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FERNS OF PARASNATH, BIHAR

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The Parasnath Hill forms a prominent feature in the landscape of South Hazaribagh. The topography, geology and climate of, and route to Parasnath Hill have been described in detail by Srivastava (1955). But to make this article complete in itself some of the points mentioned therein are repeated here.

There are two routes to the Parasnath Hill from the Parasnath railway station (locally also known as Isri). One may catch the Grand Trunk Road which will take him in a south-east direction to Nimiaghat at the southern base of the hill and a zig-zag path from here leads to the top of the hill. For the other route, again the Grand Trunk Road but in opposite direction, that is in the north-west direction, has to be covered for a short distance from where one has to proceed along the Giridih Road until he reaches another road, a branch thereof, which will take him to Madhuban at the northern base of the hill. From here a hilly track leads to the top.

The height of Parasnath Hill is 4,480 feet and its annual rainfall is about 60 inches. Relative humidity is also pretty high. That is why the hill shows a dense forest growth thus providing plenty of shade for the shade-loving plants. This at once makes it clear that the conditions of the hill are very conducive to fern growth.

The ferns of this locality have not received so much attention as the angiospermic flora, though they have been described by Beddome (1892) and Haines (1921–25). But these are more of a general nature and have become out of date with great progress in our knowledge of ferns. Even Mooney's (1950) *Supplement to the Botany of Bihar and Orissa* does not take us very far. So in this article an attempt has been made to give an up-to-date account of the ferns of the locality. Mehta (1956) has already reported three ferns from this area and these are new to Bihar.

The genera described here have been placed in the families on the basis of Copeland's (1947) classification.

Class— **FILICINEÆ**

Order **OPHIOGLOSSALES**

Family OPHIOGLOSSACEÆ

1. *Ophioglossum vulgatum* L.—Very common between 3,000 to 4,000 feet on the Madhuban side, but not on the Nimiaghat side. Haines (1921–25) has described two species of *Ophioglossum* from Bihar, *O. reticulatum* L. from Parasnath and *O. nudicaule* L. from Manbhum. Both of these, however, have been accepted by D'Almeida (1922) to be *O. vulgatum*. Some of the specimens show bifurcated spike. Very widely distributed in India.

Order **FILICALES**

Family SCHIZAEACEÆ

2. *Lygodium flexuosum* Sw.—Ascending to the top of the hill. Also in other parts of India. South India up to 4,000 feet on both sides of the Madras Presidency; North India up to 5,000 feet.

3. *Pteris quadriaurita* Retz. sens. lat.—This fern has not been described by Haines from Bihar and Orissa. But Mooney (1950) in his *Supplement to the Botany of Bihar and Orissa* describes it from Kapilas Hill (2,000 feet) in Dhenkanal, Orissa. So this will be a new record not only for Parasnath but also for the State of Bihar constituted as it is.

The material was collected by Prem Sharan, a student of mine, near a stream at about 2,000 feet and was handed over to me.

According to Mooney its distribution is throughout India from the plains up to 8,000 feet.

Now a short description of the specimen—Terrestrial; fronds uniform, pinnate with a terminal pinna; pinnæ alternate and pinnatifid, ending into a linear entire tail, glabrous; veinlets forked from their base and free except in the sori; costules prominent, the lowest vein from each costule usually meeting the lowest from the next costule and forming a low arch and giving several veinlets towards the sinus; sori continuous along the margin but avoiding the apices of the ultimate segments and usually the sinuses between them, borne on a marginal connecting vein, protected by the scarious reflexed margin, without other (true) indusium; annulus longitudinal, interrupted and composed of about 17 thickened cells.

4. *Aleuritopteris farinosa* (Forsk.) Fee.—Ascending to the top of the hill. Also in all districts of Chota Nagpur. The genus is segregated from *Cheilanthus* by Fee from which it differs in the form of the frond, in densely white ceraceous covering on the lower surface and in having few sporangia.

5. *Adiantum philippense* L.—Throughout Chota Nagpur. *A. lunulatum* Burm. is its synonym and has been described as such by Haines. Very common throughout Northern India in moist places.

Family *PARKERIACEÆ*

6. *Ceratopteris thalictroides* (L.) Brongn.—Collected from a ditch near the southern base of the hill towards Nimiaghat; very common in Purnea; common in Chota Nagpur. Only the pinnately divided aerial fertile fronds with numerous narrower segments were collected. Aquatic or sub-aquatic annuals. Widely distributed in the tropics. According to Mahabale (1948) it occurs as annuals or perennials in India and Ceylon in an amphibious state; but is also seen in floating condition in deep waters in Bengal, Assam and other parts of India. He collected it on the banks of the Sabarmati River at Ahmedabad, Western India.

Family *DAVALLIACEÆ*

7. *Araiostegia pulchra* (Don.) Copel.—Collected at about 4,000 feet, epiphyte. The genus has been included in *Leucostegia* by Beddome and Christensen (Copeland, 1947). And *Leucostegia* has been described under *Humata* by Haines. According to Copeland *Leucostegia* differs from *Araiostegia* in texture, colour, dissection of the frond and in very large sori.

8. *Leucostegia immersa* (Wall.) Presl.—Collected at about 4,000 feet, epiphyte. Its morphology has been described in detail by Kachroo (1955). It occurs in Assam at Shillong, Cherrapunji (Khasi Hills) and Imphal (North-East Frontier of India).

Family *ASPIDIACEÆ*

9. *Dryopteris cochleata* (Don.) C. Chr.—Ascending to the top of the hill and also in other areas of Bihar. Described by Haines as *Lastrea cochleata* Bedd. in which the fronds are dimorphic. This character is not mentioned by Copeland. I have the fertile as well as the sterile fronds.

10. *Tectaria macrodonta* (Fee) C. Chr.—This fern is also a new record for Bihar. It occurs between 2,000 to 3,000 feet. Its description from the specimen runs as follows:—

Terrestrial; fronds uniform, pinnatifid at the apex and pinnate below. (I have only the apical portion of the frond and further description is based on this portion alone.) Segments further pinnatifid more than halfway to the rachis, ultimate segments bluntish at the apex with crenate margin, surface glabrous on both sides; venation Sagenioid or Pleocnemioid; sori uniform, round, terminal on the veinlet and indusiate, sori generally in two rows one on each side of the main vein of the ultimate segments, but occasionally irregular; indusium round-reniform, affixed under sorus and opening around the margin; annulus longitudinal, interrupted and composed of 13 to 14 thickened cells.

11. *Cyclosorus multilineatus* (Wall.) C. Chr. & Tard.—Collected at about 3,000 feet. Described by Haines as *Nephrodium moulmeinense* Bedd. Also occurs in some other parts of Bihar.

12. *Athyrium macrocarpum* (Bl.) Bedd.—Reported for the first time from Bihar by Mehta (1956).

13. *A. drepanopterum* (Kze.) A.Br.—This species has also been reported from Bihar for the first time by Mehta (1956).

Family POLYPODIACEÆ

14. *Drynaria propinqua* (Wall. ex Mett.) J. Sm.—Like the previous two species this is also a new record for Bihar (Mehta, 1956).

Summary

In this short paper the author has described fourteen fern specimens which he collected (except *Pteris quadriaurita*) from Parasnath Hill from time to time. This description includes five fern specimens which have not been reported earlier from Bihar. Out of these five, three were reported by me in a separate communication.

The author is thankful to Principal M. Q. Doja for many courtesies and also to Prof. R. P. Roy for the facilities which he very kindly provided. Thanks are also due to the Director, Royal Botanic Gardens, Kew, for arranging the identifications of some of the fern specimens.

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SOME NEW RECORD OF PLANTS FROM THE PARASNATH HILL

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(Received for publication on May 29, 1956)

The Parasnath Hill in Chota Nagpur, which rises abruptly from the plains to an elevation of 4,480 feet above the sea-level, is the highest mountain in Bihar and is a prolongation of the north-eastern edge of the Deccan Plateau into the Gangetic plain. In a country of park-like appearance, this hill is densely forest clad from the base and the vegetation is of a mixed deciduous type, the common trees being *Shorea robusta*, *Terminalia chebula*, *Terminalia arjuna*, *Dalbergia latifolia*, *Schleichera oleosa*, *Sterculia urens*, *Lagerstrœmia parviflora*, *Randia dumetorum*, *Emblica officinalis* and *Albizzia procera*. Near the top of the hill the forest is more open with scattered stunted trees, a few shrubs and herbs and different species of tall and low grasses. A few Sub-Himalayan plants like *Berberis*, *Clematis*, *Thalictrum*, *Cardamine*, *Bulbophyllum*, *Habenaria*, *Begonia*, *Aeginetia*, *Disporum*, *Panax*, etc., occur in Parasnath in association with those of the drier southern regions. The availability of such sub-temperate or temperature species indicate that the hill has served as a stepping-stone for the passage of species from the high lands of the Indian peninsula to the Himalayas and in some cases in the reverse direction.

The Parasnath Hill attracted the attention of botanists since 1848, when it was visited by the late J. D. Hooker. An account of his visit to this locality is available in his famous *Himalayan Journal* and also elsewhere. The specimens collected by him are now preserved in different herbaria in India and Europe. After Hooker, the place was botanised by many, *e.g.*, Thompson, Anderson, Edgeworth, Clarke, Prain, Haines and others. A recent account of this area has been published by Srivastava who has given a list of *Phanerogams* collected by him, including a number of plants which happen to be new records.

In September 1955, the writer paid a short visit to this area and collected specimens for the Calcutta Herbarium. A total of about 650 specimens of 136 species of plants were collected in 2 days. This collection being small is far from complete. Yet on comparing with the recent list published by Srivastava, it was found that at least 7 species collected by the writer from the Parasnath Hill have not been recorded even by Srivastava. This is certainly interesting as Srivastava's paper was published only a few months ago. These include 2 species of ferns, which group, however, has been left out by Srivastava from his survey. These new records are listed below and the specimens referred to here have been lodged at the Calcutta Herbarium.

1. **Bidens bipinnata** Linn. (*Compositæ*)

   Near the top of the hill, about 4,000 feet. Haines has not included this in his *Botany of Bihar and Orissa* although there are several old collections from Chota Nagpur and more than one from Parasnath itself. A common pantropic weed which may have reached this area in recent years. *Mukerjee* No. 3900.

2. **Euphorbia microphylla** Heyne (*Euphorbiaceæ*)

   Open ground in front of Dak-bungalow at 4,200 feet elevation. Previously collected by J. D. Hooker on banks of streams in Bihar and also from Bettiah by Hieronymus. *Mukerjee* No. 3891.

3. **Habenaria stenopetala** Lindl. (*Orchidaceæ*)

   Found on the northern slope of the hill at an elevation of 2,000 feet. Only one specimen was found. It had been collected only once from this province by C. B. Clarke from Singbhum. *Mukerjee* No. 3971.

4. **Setaria intermedia** R. & S. (*Gramineæ*)

   Collected from near the Dak-bungalow at 4,000 feet on the hill. Recorded from many other places in Bihar-Orissa and its occurrence in Parasnath was not unexpected. *Mukerjee* No. 3930.

5. **Themeda villosa** Dur. & Jack. (*Gramineæ*)

   Found near the top of the hill above 4,000 feet. Recently H. F. Mooney found it in Bamra, Orissa. It was not known west of Assam till then. *Mukerjee* No. 3934.

6. **Tectaria macrodonta** (Fee) C. Chr. (*Aspidiaceæ*) *Syn. Aspidium cicutarium var. coadunata* Haines.

   Bot. Bihar and Orissa, **6**: 1192, 1924.

   On northern slope of Parasnath Hill, at 2,500 feet elevation. Reported to be common in Singhbum. *Mukerjee* No. 3992.

7. **Pleopeltis linearis Bedd.** (*Polypodiaceæ*)

   Found on northern slope of Parasnath Hill at an elevation of 2,500 ft. Previously reported only from Netarhat. *Mukerjee*, No. 3996.

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STUDIES ON THE CYTOLOGY AND PHYLOGENY OF THE PTERIDOPHYTES

III. Observations on *Osmunda regalis L.*

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(Received for publication on June 9, 1956)

Osmunda regalis, the only South Indian representative of the family Osmundaceæ, has very limited distribution in South India, and is confined to higher elevations. It is found in Munnar (4,500 feet), Deviculam (5,000 feet), Ponmudi (3,500 feet) and Kodaikanal Hills (7,000 feet). They grow on the sides of fast flowing streams or fresh-water lakes. When brought to the plains they do not thrive too well even under green-house conditions, though they may survive for a few years, occasionally producing fresh leaves and sporangia.

Osmunda is an easy cytological material and excellent preparations could be obtained by simple acetocarmine squash technique. The materials used in this study were collected from all the above localities. Sporangia were fixed from plants growing in the wild conditions and root tip counts were made from plants grown in the green-house. The cytological and photographic techniques followed were similar to those described earlier (Ninan, 1955, 1956 *b*).

Chromosome studies of materials collected from Ponmudi showed 22 bivalents in spore mother cells (Pl. XI, Fig. 1) and 44 chromosomes in root tip cells (Pl. XI, Fig. 2). The Munnar and Kodaikanal materials also showed 22 bivalents each during meiosis. Earlier observations made in this laboratory has shown the Deviculam material also to possess the same number of chromosomes.

Comparing the above observations with previous reports of chromosome numbers in this genus, the first thing that strikes us is the remarkable uniformity in chromosome number in all the species studied from different geographical regions. Manton (1950) reported the haploid number of $n = 22$ in garden materials of *Osmunda cinnamomea*, *O. claytoniana*, *O. palustris* and *O. gracilis* and in wild materials of *O. regalis* from the British Isles. Britton (1953) observed the same number in American materials of *O. regalis* and *O. cinnamomea*. Observation on Malayan and Ceylon materials of *O. javanica* (Manton, 1950, 1954) also showed the same number. All investigated species of this genus are thus found to be diploids with $n = 22$. In the possession of a haploid number as low as 22 and in the lack of natural polyploidy, *Osmunda* is remarkably different from most of the other genera of ancient Pteridophytes. Palæontological evidence shows that the Osmundaceous stock is traceable back in geological horizons to the Upper Permian; and in spite of the long period available for evolution to

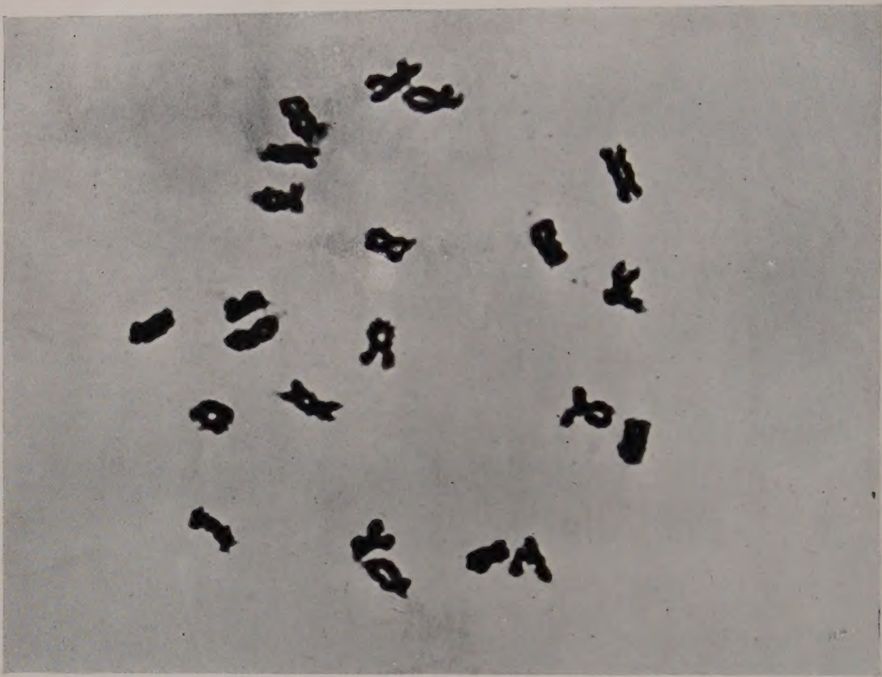


FIG. 1

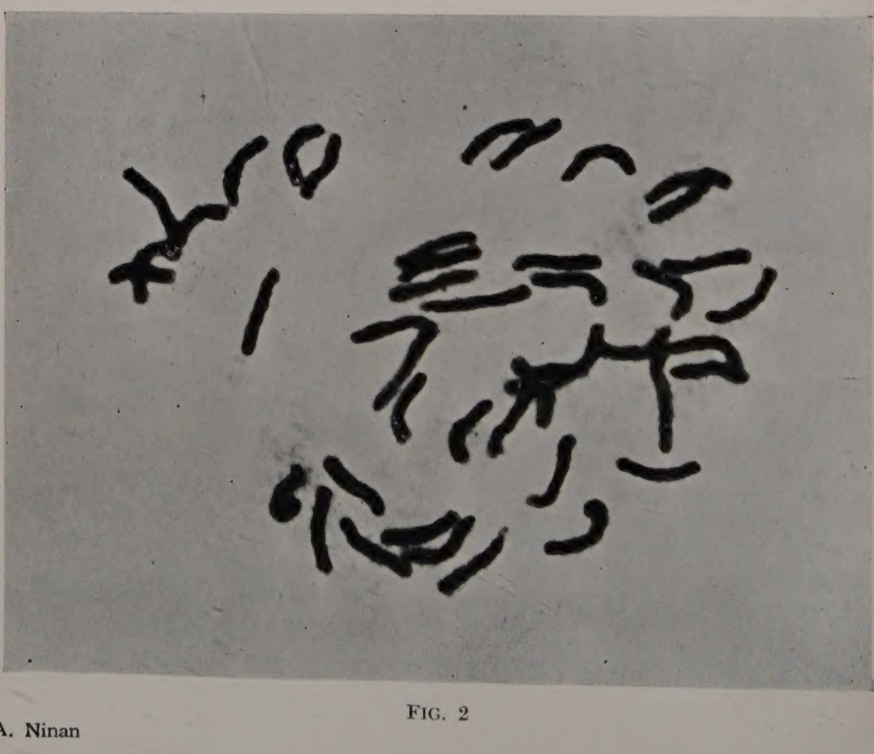
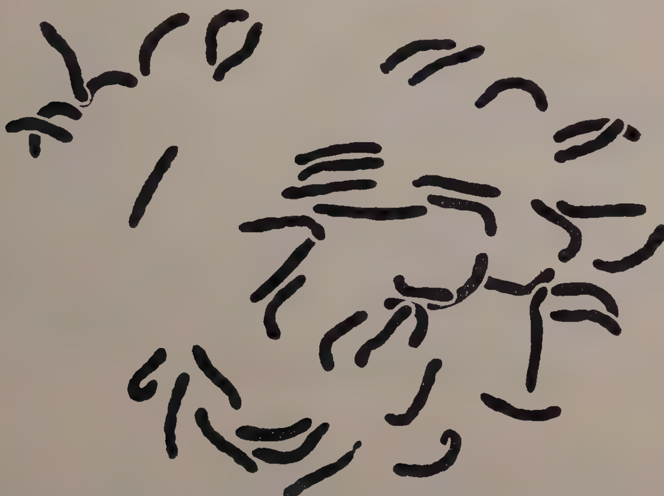


FIG. 2

C. A. Ninan

proceed, the same primitive morphological features combined with a presumably conservative cytological situation are still retained in this genus. In this sense *Osmunda* may be considered genuinely primitive.



TEXT-FIG. 1. Explanatory diagram to Plate XI, Fig. 1 showing 44 chromosomes, ×1,500.

The other two genera of the Osmundaceæ, namely, *Todea* and *Leptopteris* also possess the haploid number of $n = 22$ (Manton, 1950). It can reasonably be assumed that the number $n = 22$ might have been derived from the basic number 11. Bower (1928) has suggested the probability that *Ceratopteris* and allied genera (primitive Gymnogrammoids) "represent derivative lines which originated in relation to such antique types as the Osmundaceæ and particularly *Todea*". Evidence discussed elsewhere (Ninan, 1956 *d*) shows clearly that *Ceratopteris* is related to the Osmundaceous stock in the possession of a chromosome number which is a multiple of 11.

The Osmundaceæ is held to be a synthetic type between the Eusporangiate and Leptosporangiate ferns (Bower, 1926). The two Eusporangiate families Ophioglossaceæ and Marattiaceæ are shown to have evolved from ancestral types with 15 and 13 respectively as the basic chromosome numbers (Ninan, 1956 *a*, *b*). The ancient Leptosporangiate genera like *Gleichenia* and *Matonia* also possess a basic number of 13 (Manton, 1953 and Ninan, 1956). Other principal haploid numbers like 29, 30, 36, 37, 40 and 41, characteristic of advanced Leptosporangiate families of ferns also show no apparent relation to the number 11, which might be regarded as fundamental to the beginnings of the Osmundaceæ. It seems, therefore, clear enough, that the Osmundaceæ started as a separate line even from very early times and that they are distinct in descent from the Eusporangiate and Leptosporangiate groups.

As Eames (1936) has remarked—"the Osmundaceæ do not connect the Eusporangiates and Leptosporangiates phyletically, though it appears transitional between the Eusporangiate and the Leptosporangiate groups."

In the possession of fundamentally low chromosome numbers and in the lack of a polyploid series, the genus *Osmunda* affords comparison to the ancient genus *Selaginella*. The latter is exceptional in the Pteridophytes in the possession of a haploid number as low as 9, the lowest chromosome number reported in a Pteridophyte (Manton, 1950 and Ninan, 1956 *c*). However, *Selaginella* has succeeded in evolving several hundreds of species with differing habitat preferences. This means that apart from polyploidy, other factors, probably gene mutations, may have been operative in bringing about effective speciation in *Selaginella*. In *Osmunda*, however, all evolutionary activities are apparently at a standstill. Artificially produced polyploids in *O. regalis* (Manton, 1950) have also shown lack of survival value. The Osmundaceæ are to be regarded as representing end lines of an ancient stock which has lost all evolutionary potential.

Summary

The cytology of *Osmunda regalis* from four localities in India is described. There is remarkable uniformity in chromosome number ($n = 22$, $2n = 44$) in all the investigated species of *Osmunda* from widely separated areas. The cytological evidence supports the view expressed by Eames that Osmundaceæ does not constitute a connecting link between Eusporangiate and Leptosporangiate ferns. The Osmundaceæ stands apart from the other Pteridophyte families and is in all probability the end line of an ancient stock.

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————. 1956 *e*. Cytology of *Psilotum nudum* L. *La Cellule*, **57** (in press).

EXPLANATION OF PLATE XI

FIG. 1. Diakinesis in a spore mother cell of *Osmunda regalis* L. 22 bivalents are clearly seen, $\times 1{,}500$.

FIG. 2. Somatic mitosis from a root tip squash in *O. regalis* L. $2n = 44$, $\times 1{,}500$.

STUDIES ON THE CYTOLOGY AND PHYLOGENY OF THE PTERIDOPHYTES

IV. Systematic Position of *Ceratopteris thalictroides* (L.) Brongn.

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(Received for publication on June 9, 1956)

Ceratopteris is an aquatic annual consisting of 2–4 species widely distributed in the tropics. *Ceratopteris thalictroides* (L.) Brongn. is the only species that is indigenous to South India. It is found throughout the low lands as a weed in rice fields and by the sides of streams in shallow water.

Ceratopteris is a genus of very doubtful affinities and hence the assigning of a proper systematic position for this genus has for long been a difficult problem to Pteridologists. Different authors have treated it in quite different ways in their classifications. It is accepted by all that a valid phylogenetic system can be evolved only by the exercise of all available criteria for comparison (Bower, 1923 and Wagner, 1952). Due to lack of information on certain important aspects like cytology and gametophyte phase it has not been possible to come to any definite conclusion regarding the systematic position of certain problematic genera.

In *Ceratopteris*, though we have information on the gametophyte (Kny, 1875 and Mahabale, 1948) details of the cytology are not yet clearly known. The present paper attempts to fill this gap.

Materials for investigation were obtained from Veli near Trivandrum City. The cytological and photographic techniques followed were similar to those described earlier (Ninan, 1955, 1956 *a*).

Preparations of somatic mitosis made from root tips showed 154 chromosomes at metaphase (Pl. XII, Fig. 1 and Text-Fig. 1). Meiotic counts clearly showed 77 bivalents (Pl. XII, Fig. 2 and Text-Fig. 2). Manton (1954) has reported the presence of 76–78 bivalents in Malayan materials of *Ceratopteris thalictroides*. The present study has shown very clearly that the haploid chromosome number for this genus is exactly 77.

The somatic chromosomes are fairly large in size in spite of the high chromosome number and they are all nearly of the same length. Most of them have median or sub-median constrictions and two show satellites. Some of the meiotic chromosomes show "antenna-like" shapes reminding one of the chromosomes of *Lycopodium inundatum* described by Manton (1950). Both meiotic and mitotic chromosomes take very good stain and excellent preparations could be obtained even with 12–24 hours of fixation.

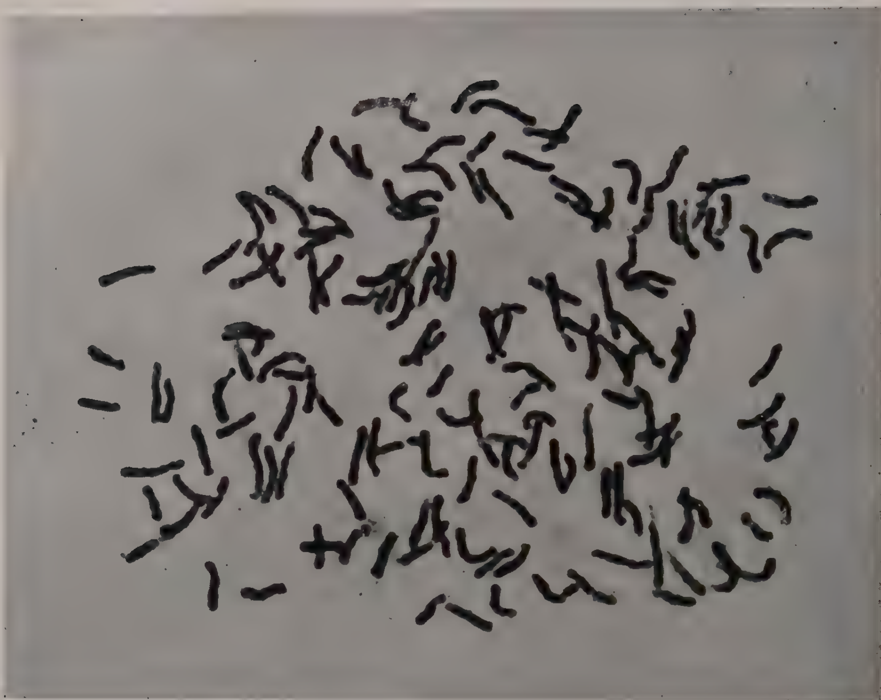


FIG. 1

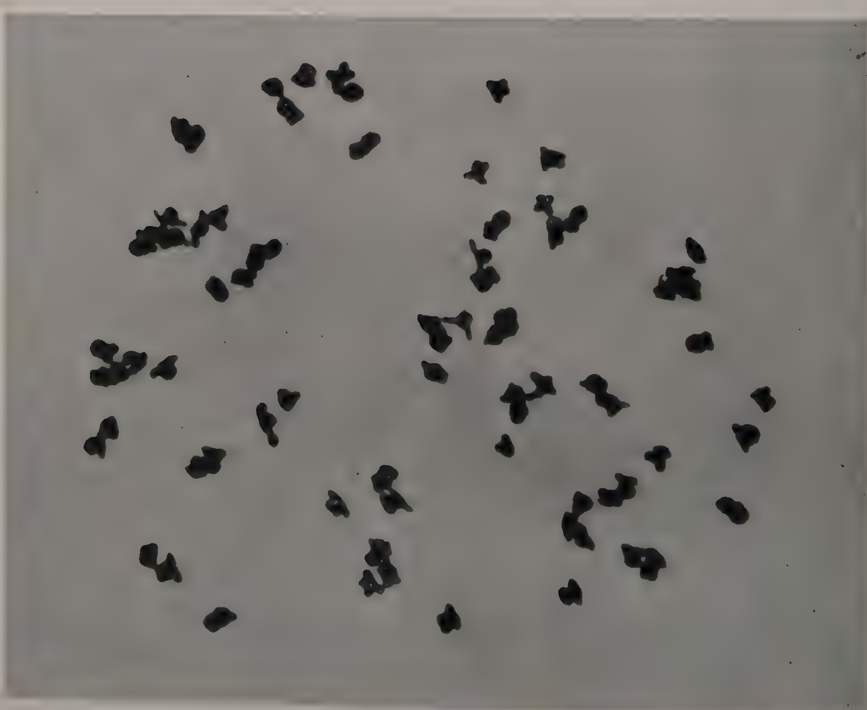
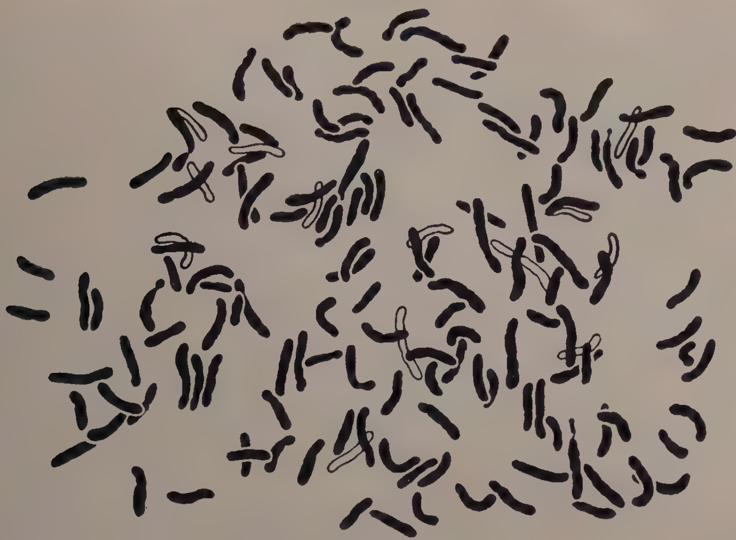


FIG. 2

C. A. Ninan



1

2

TEXT-FIGS. 1–2. Fig. 1. Explanatory diagram to Plate XII, Fig. 1 showing 154 chromosomes in root tip squash, ×1,200. Fig. 2. Explanatory diagram to Plate XII, Fig. 2, showing 77 bivalents at I metaphase of meiosis in spore mother cell, ×1,500.

Discussion

The family Parkeriaceæ (Ceratopteridaceæ) was established by Hooker in 1825 to accommodate the genus *Ceratopteris*. Diels (1900), Ching (1940) and Copeland (1947) maintain this as a separate family. Christensen (1938) includes the genus in Polypodiaceæ (sub-family Gymnogrammoideæ, tribe Ceratopterideæ), while Holttum (1947) relegates it to Adiantaceæ. Bower (1928) associates it with the Gymnogrammoid group of genera, with many of which it shares features like the arrangement of sporangia along the veins and large short-stalked sporangia with irregular annulus. He believes that the primitive Gymnogrammoideæ (including the genera *Llavea*, *Onychium*, *Jamesonia*, *Cryptogramme* and *Ceratopteris*) have originated from types with superficial sporangia like *Todea* or *Plagiogyria* and that these five genera are probably related to one another. Holttum (1947) lends support to Bower's view and regards it as more plausible than any other. He (1954) states "*Ceratopteris* is undoubtedly a specialised genus and not closely related to the other Gymnogrammoid ferns which are mainly xerophytic, but most probably it comes of the same stock". Christensen (1938) while supporting Bower's view in the main, is sceptical about the interrelationships of the various genera of Bower's primitive Gymnogrammoideæ. He regards the Gymnogrammoids as a group of uncertain mutual relationship probably representing different lines of evolution. Copeland (1947) considers that the genus *Ceratopteris* is derived from indusiate ancestors. He comments: "I let the genus stand as a family because the degeneration of the sporangial structure has taken it beyond easy inclusion in any family description of *Pteridaceæ*; but do not doubt that it is derived from that family as here construed." On the contrary, Bower (1928) is of opinion that "the primitive Gymnogrammoids stand phyletically on their own feet distinct in descent from the Pteroid ferns".

Out of the 5 genera of Bower's primitive Gymnogrammoideæ, the cytology of *Ceratopteris* and *Cryptogramme* are now known. The latter has a chromosome number of $n = 30$ a number so characteristic of most of the Gymnogrammoid, Pteroid, Adiantoid and Cheilanthoid ferns (Manton, 1950, 1954 and Ninan, unpublished observations). *Cryptogramme* therefore aligns itself very closely with the Gymnogrammoids. But *Ceratopteris* with a haploid chromosome number of $n = 77$ can in no way be related to *Cryptogramme*, which in the light of other evidences, is considered (Bower, 1928 and Christensen, 1938) to be a close relative of *Ceratopteris*. Though the cytological situation in *Llavea*, *Onychium* and *Jamesonia* are not yet known, the disparity in chromosome numbers evidenced by *Ceratopteris* and *Cryptogramme* is itself clear indication that the primitive Gymnogrammoids of Bower represent more than one evolutionary line. The Gymnogrammoid state as shown by these genera might be the result of parallel evolution and it cannot be construed as indicating closer relationship.

Cytological evidence also shows clearly that Holttum's inclusion of *Ceratopteris* in his Adiantaceæ (1947) is the result of an inadequate

appreciation of the affinities of the genus. Recent observations have shown that all the genera of Holttum's Adiantaceæ like *Monogramma*, *Vittaria*, *Antrophyum*, *Syngramma*, *Doryopteris*, *Hemionitis*, *Adiantum*, *Coniogramme*, *Pityrogramma* and *Cheilanthes* (except *Tænitis*, the cytology of which is not known) are characterised by the presence of numbers like 29 or 30 or their multiples (Manton, 1954 and Ninan, unpublished observations). The presence in *Ceratopteris* of a haploid chromosome number of $n = 77$ at once suggests discord in an otherwise cytologically homogeneous group. There is thus sufficient reason for separating *Ceratopteris* from Holttum's Adiantaceæ.

Copeland's contention that *Ceratopteris* is derived from indusiate ancestors, most probably from the Pteroid ferns is also not in agreement with evidence from cytology. The close affinity of *Ceratopteris* with the *Cheilanthes* group of ferns (Copeland, 1947 and Stokey, 1951) is equally unconfirmed. However Bower's suggestion of an origin of *Ceratopteris* from Osmundaceous ancestors gains support in that all the living genera of the Osmundaceæ and *Ceratopteris* are traceable back to 11 chromosomed ancestors (Ninan, 1956 *b*).

Coming to purely cytological considerations, the nature of the somatic chromosomes in *Ceratopteris* also supports an ancestry from some primitive group. The chromosomes closely resemble those of some of the ancient genera of Pteridophytes like *Psilotum* and *Angiopteris*, in the large size of the chromosomes in spite of high numbers. The other genera included by Holttum in Adiantaceæ and which have been investigated in this laboratory all show much smaller somatic chromosomes even where the number is appreciably smaller (Ninan and Mathew, unpublished observations). This clearly shows that on cytological grounds *Ceratopteris* stands in a position distinct from these genera.

Evidences already discussed provide sufficient warranty for the separation of *Ceratopteris* from the taxonomic groupings of Bower and Holttum. Bower's view that the genus probably represents a distinct line of evolution from some primitive stock in close relation to the Osmundaceæ seems more palusible in the light of evidence from cytology. Copeland's assignment of family status to the genus appears to be the best taxonomic arrangement. In the peculiar blending of advanced and primitive characters *Ceratopteris* seems to be a specialised genus which occupies an isolated position.

Summary

The cytology of *Ceratopteris thalictroides* is described. It has a chromosome number of $n = 77$ and $2n = 154$. The chromosomes are large in size in spite of the high number, and in this respect recall the condition in *Psilotum* and *Angiopteris*.

The systematic position of *Ceratopteris* is discussed in the light of cytological data of supposedly related genera and it is shown that Copeland's treatment of the genus as the only representative of the family, Parkeriaceæ, appears to be the most satisfactory.

Acknowledgement

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Explanation of Plate XII

Fig. 1. *Ceratopteris thalictroides* (L.) Brongn. Root tip squash showing a somatic number of $2n = 154$, $\times 1{,}200$.

Fig. 2. Meiosis in *Ceratopteris thalictroides*, 77 bivalents are clearly seen, $\times 1{,}500$.

FOSSIL SILICOFLAGELLATES FROM COLEBROOK AND NANCOORI ISLANDS

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Introduction

The Silicoflagellates constitute a very small group having only a few genera. These are known from the Cretaceous to the present day (Fritsch, 1935, p. 558) and their distribution through the geological period is of considerable significance and is often reckoned as evidence in deciding the geological age of any particular deposit.

The silicoflagellates have been recorded from various parts of the world. From India Ehrenberg (1851, 1854) has recorded a few forms from the Nancoori fossil deposits in the Nicobars. Recently Jacob and Shrivastava (1952) have recorded a *Dictyocha* (D. sp.) from fossil deposits in the Colebrook Island in the Ritchie's Archipelago of the Andamans.

The Director, Geological Survey of India, kindly sent the authors some material from the Colebrook Island fossil deposits. A study of this material revealed a few interesting forms. The writers had also an opportunity of studying the original diatom slides prepared from the Nancoori deposits, collected by Grunow and distributed by Cleve and Möller (1878, Slide Nos. 162, 163). The writers found in these two slides, in addition to the diatoms, a number of silicoflagellates also. The silicoflagellates from the Nancoori Deposits are also included in this paper.

Description of the Species

Mesocena Ehrbg.

M. polymorpha Lemm., var. *triangula* (Ehrbg.) Lemm.

(Text-Fig. 7)

Gemeinhardt, *Silicoflagellatæ*, 29, fig. 12 *c*, 1930.

Basal ring somewhat triangular with convex sides; angles with three short spines, 3·5–5 μ long, distance between neighbouring spines 42–47 μ; surface rough, ornamented with small protuberances (Plate XIII, Fig. 1).

Nancoori deposit.

Only a single specimen of this species has been observed in Cleve and Möller's Slide No. 163.

M. polymorpha Lemm., var. *quadrangula* (Ehrbg.) Lemm.

(Text-Figs. 1, 3, 5)

Gemeinhardt, *Silicoflagellatæ*, 29, fig. 13, 1930.

Basal ring roughly quadrangular with slightly convex sides, 51–66 μ diameter; surface rough, ornamented with small protuberances; sides 39–42·5 μ long; spines 3–6 μ long (Plate XIII, Fig. 2).

Nancoori deposit.

In one specimen a long narrow inward projection is seen from one of the sides. Of interest is the form in Fig. 5, which simulates var. *triangula* but has a fourth very small spine.

Dictyocha Ehrbg.

D. tricantha Ehrbg., f. *minor* Schulz.

(Text-Fig. 2)

Gemeinhardt, *Silicoflagellatæ*, 40, fig. 29 *a*, 1930.

Basal ring triangular, sides convex slightly depressed in the middle, one side 19–20 μ long; the angles produced into spines; spines up to 8 μ long; chambers three, subequal in size (Plate XIII, Fig. 3).

This species occurred only sparsely in the Colebrook material.

D. fibula Ehrbg.

Gemeinhardt, *Silicoflagellatæ*, 47, 1930.

Basal ring quadrangular, rhombic, oval or almost orbicular; angles produced into four spines in two opposite pairs; spines up to 10 μ long; on the basal ring usually four small inwardly projecting spines present; surface smooth or rough; four basal rods or arms meeting in pairs and connected by a transverse bar; basal ring with four chambers, of which two are usually smaller than the opposite pair.

D. fibula Ehrbg. and *D. fibula* f. *aspera* Lemm. have been earlier recorded from Nancoori. These forms have not been seen in the present investigation.

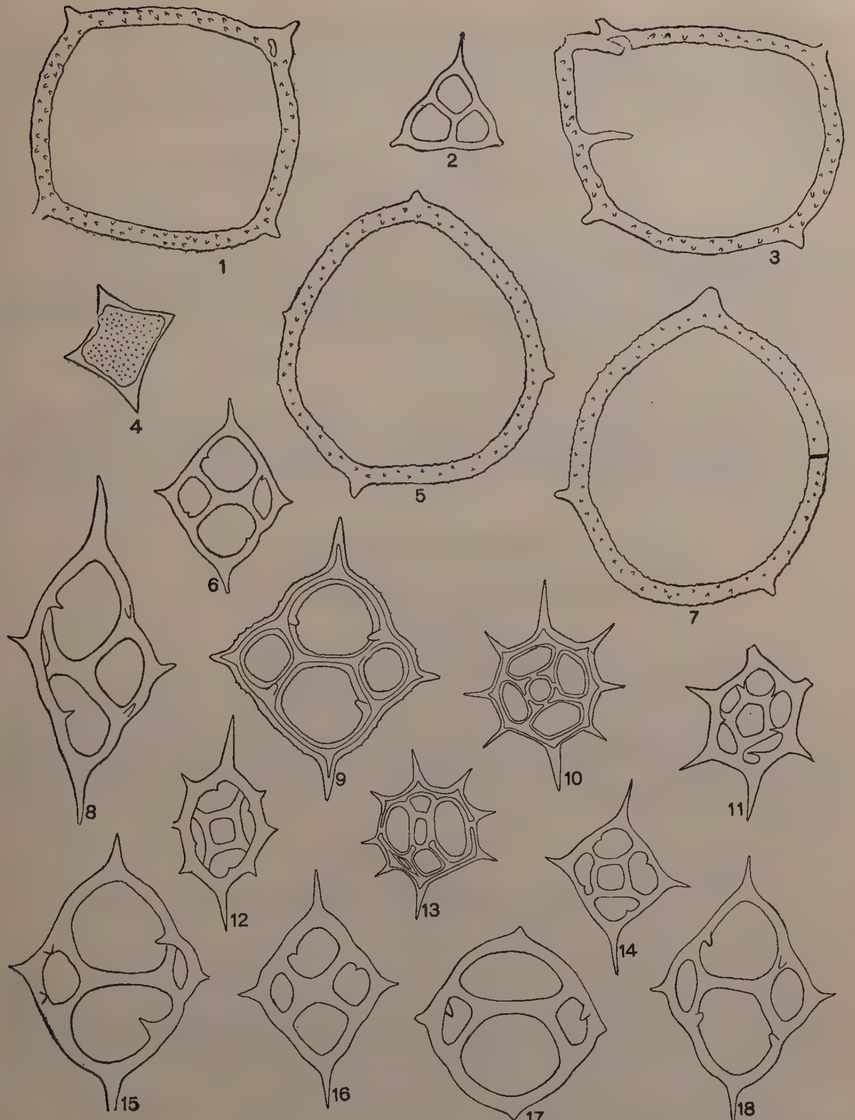
D. fibula Ehrbg., f. *rhombica* Schulz.

(Text-Figs. 6, 8, 9, 15–18)

Gemeinhardt, *Silicoflagellatæ*, 50, fig. 40, 1930.

Basal ring rhombic, 27–39 μ long and 20–35 μ broad; angles produced into four spines in two opposite pairs, spines 3–10 μ long; on the basal ring four small spines; surface smooth or rough; the four rods of the basal ring meeting in pairs and united by a transverse rod in the direction of the shorter axis; basal ring with four chambers, of which two are smaller than the opposite pair (Plate XIII, Figs. 5, 6).

Nancoori and Colebrook deposits.



TEXT-FIGS. 1–18. Figs. 1, 3, 5. *Mesocena polymorpha* Lemm. var. *quadrangula*. (Ehrbg.) Lemm., from Nancoori (× 300). Fig. 2. *Dictyocha tricantha* (Ehrbg.) f. *minor* Schulz., from Colebrook Island (×300). Fig. 4. *Dictyocha siderea* Schulz. var. *quadrata* Schulz., from Nancoori Island (×300). Figs. 6, 8, 9, 15–18. *Dictyocha fibula* Ehrbg. f. *rhombica* Schulz., showing variations, Figs. 9 and 18 from Nancoori, and the rest from Colebrook Island (Figs. 8, 15, 17. ×430; Figs. 6, 9, 16, 18: ×300). Fig. 7. *Mesocena polymorpha* Lemm. var. *triangula* (Ehrbg.) Lemm., from Nancoori Island (×300). Figs. 10, 12, 13. *Distephanus crux* (Ehrbg.) Haeckel var. *octacanthus* var. nov., from Nancoori Island (Fig. 12 shows 4 small spines on the inside of the basal ring), (×300). Fig. 11. *Distephanus speculum* (Ehrbg.) Haeckel, from Nancoori Island (×300). Fig. 14. *Distephanus crux* (Ehrbg.) Haeckel, from Nancoori Island (×300).

This form is very variable. Of interest is the form represented in Text-Fig. 17, which is very nearly round. It resembles very much forma *rotundata* Schulz., but differs in having four spines instead of two. Of similar interest is the form in Text-Fig. 16 (*cf.* Gemeinhardt, 24, fig. 8 *a*).

D. siderea Schulz. var. *quadrata* Schulz.

(Text-Fig. 4)

Gemeinhardt, *Silicoflagellatæ*, 56, fig. 48, 1930.

Basal ring four-sided, size $13 \times 17\,\mu$; spines four, short, $3–5\,\mu$ long; the central plate covered with numerous minute irregularly arranged granules (Plate XIII, Fig. 4).

Nancoori deposit.

A single specimen of this was found inC leve and Möller's Slide No. 163. This specimen differs from the type in having a smaller basal ring and shorter spines.

Distephanus Haeckel

D. crux (Ehrbg.) Haeckel

(Text-Fig. 14)

Gemeinhardt, *Silicoflagellatæ*, 58, fig. 49, 1930.

Basal ring rhombic to elliptical, diameter $18–24\,\mu$; end-spines $5–10\,\mu$ long; four small inwardly projecting spines; apical ring quadrangular; basal ring and apical ring connected by four silicate rods, forming four subequal basal chambers; surface smooth (Plate XIII, Fig. 7).

Nancoori deposit.

D. crux (Ehrbg.) Haeckel var. *octacanthus* var. nov.

(Text-Figs. 10, 12, 13)

Annulus basalis octogonus, $19–26 \times 15 \cdot 5–20 \cdot 5\,\mu$, octo spinis radiantibus ornatus, quarum duo longiores sunt cœteris; longiores spinæ $8 \cdot 5–10\,\mu$ longæ, breviores vero $3 \cdot 5–5\,\mu$ longæ; annulus basalis 4-locularis; annulus apicalis quadratus; facies levis.

Typus lectus in Nancoori, et positus in Herb. Crypt. Mus. Hist. Nat., Paris (Cleve and Möller sub-numero 163).

Basal ring octagonal, somewhat longer in the direction of the longer spines, size $19–26 \times 15 \cdot 5–20 \cdot 5\,\mu$, with eight radial spines, two opposite ones longer than the other six; the longer spines $8 \cdot 5–10\,\mu$ long, and the shorter spines $3 \cdot 5–5\,\mu$ long; basal ring with four chambers; apical ring quadrate; surface smooth (Plate XIII, Figs. 8, 9).

Nancoori deposit; type in Cleve and Möller, Slide No. 163 in Herb. Crypt. Mus. Hist. Nat., Paris.

This variety by its characteristic eight spines is easily distinguished from the other known varieties of *Distephanus crux*.

D. speculum (Ehrbg.) Haeckel

(Text-Fig. 11)

Gemeinhardt, *Silicoflagellatæ*, 61, 1930.

Basal ring nearly round, six-sided, 19–24 μ long and 17–19 μ broad; produced into six spines of which two are longer (8·5–15 μ) and four shorter (5–8·5 μ); equal number of small spines inwardly projecting from the sides; basal ring with 5–7 chambers.

Nancoori deposit.

The present form is somewhat different from the type. The number of chambers in the basal ring has been observed to vary from 5–7, though there are only six long spines as in the type. The apical ring has a single chamber as in the type.

Cannopilus Haeckel

C. hemisphæricus (Ehrbg.) Haeckel

(Text-Fig. 19)

Gemeinhardt, *Silicoflagellatae*, 76, fig. 63, 1930.

Basal ring hexagonal, about 23·8 μ broad; capsule hemispherical, with spines at the angles, the erect spines longer, 17 μ long, the others short, up to 7·0 μ long; apical ring many chambered, with short spines.

TEXT-FIG. 19. *Cannopilus hemisphæricus* (Ehrbg.) Haeckel from Nancoori Island (×1360).

Nancoori.

A single distinct specimen of this species was found in Cleve and Möller's Slide No. 162. The form agrees very closely with the type, but is somewhat smaller in size. This species has so far not been reported from Nancoori.

Discussion

Three species and one form have been previously known from the Nancoori deposits, *viz.*, *Mesocena polymorpha* var. *quadrangula*, *Dictyocha fibula*, *D. fibula* f. *aspera* and *Distephanus speculum*. The present study has revealed three more species and one new variety from the same area. *Dictyocha* sp. (= *D. fibula*) was the only species known from the Colebrook Island. One more interesting species, *D. tricantha* was found in the Colebrook deposit in the present investigation.

Nancoori deposits have been known to belong to the Miocene period. Some discussion has been going on regarding the age of the Colebrook Island deposits. According to Oldham (1885), Gee (1926) and Jacob and Shrivastava (1952) it belongs to the Miocene. S. R. N. Rao (1942) suggests a late Oligocene or an early Miocene age. Boileau (1950 *ex.* Jacob and Shrivastava, 1952; see also table in Jacob, 1954, p. 399), however, refers these to the pre-upper (or lower) Oligocene.

The above conclusions on the age of the Colebrook deposit are mostly based on evidence from the Radiolarian and Foraminiferous fossils. However, in recent studies great stress is laid on evidence from the distribution of Silicoflagellates though not to the exclusion of evidence from the Radiolarians, Diatoms, etc. In fact, Hanna (1927–28) says, "...... the Silicoflagellata as a group furnish most trustworthy horizon-markers." Silicoflagellates have been known only since the Cretaceous. Forms such as *Dictyocha tricantha* have been generally regarded as more primitive (Fritsch, 1935, p. 558). Haeckel (1887), however, suggests that *Mesocena* is the more primitive. Hanna (1927/28, p. 260) has very correctly pointed out that *Mesocena* is found only later than *Dictyocha*, which alone is found in the Cretaceous.

The genus *Mesocena* is definitely known to occur in the Miocene deposits of Nancoori. These have not been found in the Colebrook deposit in spite of careful search. Again in the Colebrook deposit is found *Dictyocha tricantha* which has not been observed in the Nancoori material. How the absence of the one and the presence of the other helps in finally deciding the age of the deposit is not known. But these, at any rate, suggest that the two deposits are not of simultaneous origin, and that the Colebrook deposit is probably earlier in origin than the Nancoori. This conclusion supports S. R. N. Rao's view that the Colebrook deposits may be of early Miocene or Oligocene age.

In this connection it may be mentioned that there is considerable similarity between the diatom floras of Colebrook and Nancoori deposits. Of interest is the occurrence of the very rare diatom *Coscinodiscus paleaceus* which was first described from Nancoori (Grunow, in *Van Heurck*, 1880–85). Frequency in the occurrence of this species is greater than in the Nancoori slides. This diatom has since been reported from the Naparima beds of Trinidad (Rattray, 1889). From these beds, a single Silicoflagellate, *viz.*, *Distyocha fibula*, has been described. No other Silicoflagellates appear to have been reported from Naparima beds.

Surprisingly enough, the same stratigraphical problem as regards the Colebrook deposits exists in the Naparima deposits also. Boileau (see Jacob, 1954) thinks that no real Miocene beds are present in the Andamans and suggests an Oligocene age, while others suggest a Miocene age. Similar view has been expressed in the case of Naparima too by Dall (see Reed, 1921, p. 183). According to him the Naparima formation belongs to the Upper-Oligocene and he denies the presence of any true Miocene beds in Trinidad. Recently, however, Waring (see Reed, 1946, p. 270) suggested a Lower Middle Miocene derivation.

It would be difficult to make any affirmative conclusion regarding the age of the Colebrook Island deposit. The writers can only repeat the suggestion that they made earlier in the discussion that these beds are of an earlier origin than the Miocene Nancoori.

Summary

An account is given of fossil silicoflagellates from deposits in Nancoori and Colebrook Islands. In all are described eight forms from Nancoori and two from Colebrook Island. One new variety *Distephanus crux* var. *octacanthus* is described from the Nancooris.

It is suggested that the Colebrook Island may belong to an earlier age than the Miocene Nancoori.

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EXPLANATION OF PLATE

PLATE XIII

FIG. 1. *Mesocena polymorpha* Lemm. var. *triangula* (Ehrbg.) Lemm., from Nancoori Island (×520).

FIG. 2. *Mesocena polymorpha* Lemm. var. *quadrangula* (Ehrbg.) Lemm., from Nancoori Island (×520).

FIG. 3. *Dictyocha tricantha* Ehrbg. f. *minor* Schulz., from Colebrook Island (×1,060).

FIG. 4. *Dictyocha siderea* Schulz. var. *quadrata* Schulz., from Nancoori Island (×650).

FIGS. 5, 6. *Dictyocha fibula* Ehrbg. f. *rhombica* Schulz., Fig. 5 from Colebrook and Fig. 6 from Nancoori Islands (×650).

FIG. 7. *Distephanus crux* (Ehrbg.) Haeckel from Nancoori Island (×1,060).

FIGS. 8 & 9. *Distephanus crux* (Ehrbg.) Haeckel var. *octacanthus* var. nov. from Nancoori Island (×650).

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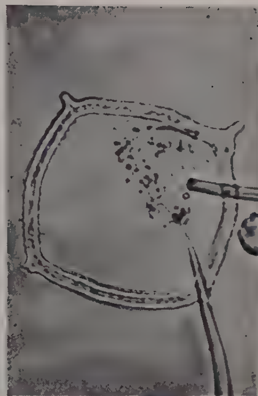

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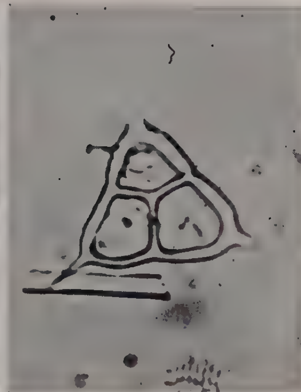

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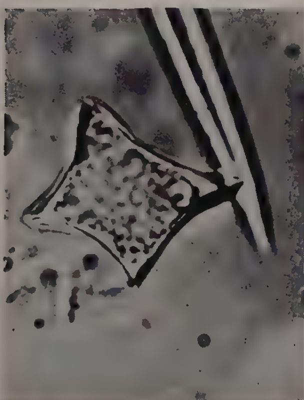

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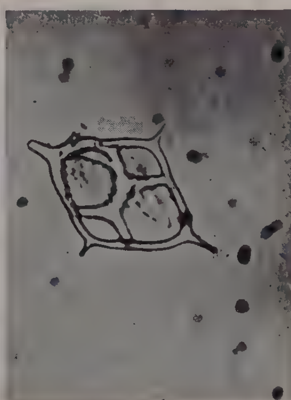

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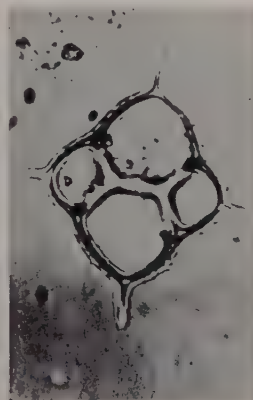

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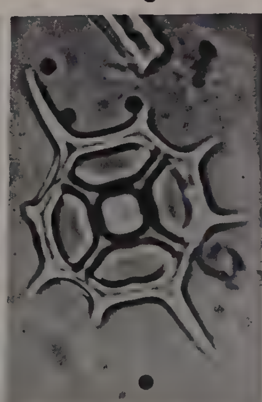

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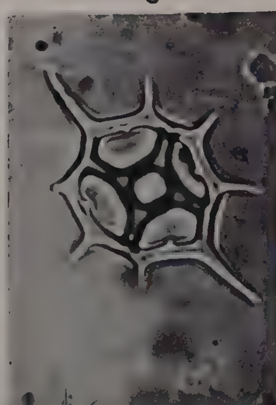

9

T. V. Desikachary & C. L. Maheshwari

ANNUAL FORAY OF THE INDIAN BOTANICAL SOCIETY TO BUND BARETA, AGRA, ON JANUARY 7, 1956

By H. Santapau, S.J., F.N.I.

(Received for publication on May 15, 1956)

The annual excursion of the Indian Botanical Society was held this year in the neighbourhood of Agra; the spot selected was Bund Bareta, about 45 miles from Agra. A good number of members joined the excursion, among them professors and research students of Agra, Banaras and Bombay Universities; the outing was a great success from every point of view.

On leaving the railway station, the party traversed a stretch of sandy fields, which during the more favourable part of the year seem to be under cultivation. Some distance from the station there is a small hill of great interest; the plains at the foot of the hill are barren waste lands, where intensely xerophytic plants seem to dominate the field; we noticed large clumps of *Zizyphus*, dense clumps of *Sericostoma pauciflorum*, bushes of *Capparis decidua* and *Leptadenia pyrotechnica*; in the middle of these spiny plants some smaller, slender plants found refuge and protection against grazing animals.

In the open fields a few notable plants were found: *Arnebia hispidissima*, *Polycarpæa corymbosa*, etc. These plants showed stout, straight roots, out of all proportion to the overall size of the plant.

The hill is rather rocky and dry; under the shelter of rocks a few fresh plants managed to find refuge, among them some of the commoner ferns of the area (*Actinopteris*, etc.). The trees on the side of the hill facing the station are small, rather stunted and woody. We noticed *Anogeissus pendula*, *Gymnosporia spinosa*, *Acacia arabica*, etc., the first of these being the more common. On the very top of the hill *Anogeissus* assumes a rather striking cushion form; the tree grows more or less flat on the ground, about 30–50 cm. high, branches spreading horizontally and rather dense, so that each tree forms a solid cushion on which it is possible to stand quite comfortably.

For the rest the components of the drier parts of the country about Bund Bareta showed a striking similarity to the plants seen, *e.g.*, on the south-western parts of Saurashtra.

The slopes of the hill facing the large water reservoir are even drier than the northern ones. Climbing down the slopes became rather difficult on account of the steep nature of the slope and of the many loose stones covering the ground. There are fewer trees on this side of the hill, but at the base there is a group of *Wrightia* that deserve attention; the trees at first appeared like some intermediate form between *W. tinctoria* and *W. tomentosa*, but are definitely not *W. tomentosa*.

In the neighbourhood of the water reservoir, we found a number of the commoner weeds of cultivated fields (*Anagallis*, *Veronica*, *Ageratum*, etc.). The large deep pools below the reservoir showed some interesting water plants, mainly water ferns, and dense masses of *Typha*, but these plants could not be collected on account of the depth of the pools.

In the following list, plants are given in alphabetical order, the names of the families being left out for the sake of brevity; after the name of each plant, refeience is made to Duthie's " Flora of the Upper Gangetic Plain" in brackets. Where nomenclatural changes have been introduced, the correct name is given first, then the name of Duthie's Flora; on purpose the synonymy of plants has been left out. Interested readers may be referred to several works by the author, among them: " Flora of Khandala " in *Rec. bot. Surv. India* **16** (1); " Plants of Saurashtra—A Preliminary List ", Rajkot, 1953; and several other minor papers. The numbers given after some of the plants refer to the collections made by my assistant, N. A. Irani, B.Sc., and preserved in Blatter Herbarium, Bombay.

1. *Acacia arabica* Willd. (Duthie **1**: 314).

   Occasional on hill slopes; many trees at the further end of the large reservoir; some large trees in cultivated fields along the road.

2. *Acacia leucophlœa* Willd. (**1**: 315).

   Saw one tree with plenty of fruit, near road at foot of hill.

3. *Acacia senegal* Willd. (**1**: 317).

   Rare; seen on the slopes of the hill.

4. *Achyranthes aspera* Linn. (**3**: 18).

   Occasional in fruit and leaf, on plains and hill slopes.

5. *Actinopteris* spec.

   Sterile fronds only, in sheltered spots on upper parts of hill, rather common.

6. *Adhatoda vasica* Nees.

   Justicia adhatoda Linn. (**2**: 207).

   Common and abundant, small clumps on the hill; in flower and fruit; only about 50–75 cm. high. (I. 1642).

7. *Ageratum conyzoides* Linn. (**1**: 443).

   In moist cultivated fields below reservoir; flowers uniformly light blue only.

8. *Albizzia lebbeck* Benth. (**1**: 320).

   Planted along roads, with plenty of fruits; large trees.

9. *Anagallis arvensis* var. *cærulea* Gren. & Godr.
Anagallis arvensis Duthie, non Linn. nisi pro parte. (**2**: 6).
In cultivated fields below reservoir, locally rather abundant, flowers bright blue. (I. 1639).

10. *Andrographis echioides* Nees. (**2**: 197).
On higher slopes, locally in small clumps, in fruit; 10–20 cm. high only.

11. *Andrographis paniculata* Nees. (**2**: 196).
On the upper parts of the hill slopes; rather similar in general appearance to *Peristrophe*, from which the type of corolla at once distinguishes it.

12. *Anisochilus carnosus* Wall. (**2**: 240).
Several dry plants with clear remains of inflorescence, but leafless, on upper part of hill (I. 1645).

13. *Annona squamosa* Linn. (**1**: 23).
Small trees, cultivated below reservoir.

14. *Anogeissus pendula* Edgew. (**1**: 339).
About the commonest tree on the slopes of the hill, in fruit; forming cushions on the very highest part of hill. (**1**: 1649).

15. *Argemone mexicana* Linn. (**1**: 36).
Common and rather abundant along the road from the village to the hill, often in flower. This plant seems to be larger and greener than in Bombay.

16. *Aristolochia indica* Linn. (**3**: 44).
Large climber in fruit and leaf; collected seeds for planting. (I. 1648).

17. *Arnebia hispidissima* DC. (**2**: 97).
Flowers yellow; leaves forming rosette on ground; tap root stout and long. In open sandy fields (I. 1657).

18. *Azadirachta indica* Juss.
Melia azadirachta Linn. (**1**: 150).
Only seen in leaf; planted along roads, much damaged from constant cutting of branches.

19. *Barleria prionitis* Linn. (**2**: 200).
Small plants; remains of flowers; small clumps about the middle of the hill.

20. *Bidens* spec.
Collected several dry plants in fruit, leafless, 30–45 cm. high; about the middle of the slopes it is locally abundant.

21. *Blainvillea latifolia* (L. f.) DC.
B. rhomboidea Cass. (**1**: 469).
Dry plants in fruit, abundant in plains, among clumps of spiny plants.

22. *Blepharis maderaspatensis* Roth.
B. bœrhaviæfolia Pers. (**2**: 183).
On the slopes of hill, fairly common, in flower.

23. *Blepharis molluginifolia* Pers. (**2**: 183).
At the foot of the hill and on the lower slopes.

24. *Blumea* spec.
In leaf only; strongly scented and rather hairy. Common on plains, scarce on hill.

25. *Borreria hispida* (L.) Schum.
Spermacoce hispida Linn. (**1**: 429).
A few prostrate plants, mostly dry, some in fruit; plains.

26. *Borreria stricta* (L. f.) Schum.
Spermacoce stricta Linn. f. (**1**: 429).
Common and abundant on hill slopes, dry plants; but the fruit and leaves are typically those of *Borreria stricta* and not of *Anotis* spec.

27. *Calotropis procera* R. Br. (**2**: 48).
About 1·5 m. high, in flower; common on plains, rare on hill.

28. *Capparis decidua* (Forsk.) Pax.
C. aphylla Roth. (**1**: 53).
On plains, in waste lands, in clumps up to 1·5 m. high, about 1 m. diam.; leafless. Many interesting unarmed plants seem to find shelter from grazing animals under this plant.

29. *Capparis zeylanica* Linn.
C. horrida Linn. f. (**1**: 53).
Subscandent shrubs in leaf only, on hill; rare.

30. *Cardiospermum halicacabum* Linn. (**1**: 178).
A few plants in fruiting condition on plains and hill; rare.

31. *Carica papaya* Linn. (**1**: 383).
Flowers and fruits; cultivated in garden below reservoir.

32. *Cassia absus* Linn. (**1**: 294).
Very small plants in flower; rare; near base of hill.

33. *Cenchrus setigerus* Vahl.

C. biflorus of the Fl. Brit. Ind., non Roxb.

Upper slopes and top of hill, not common. One of the few grasses seen to-day.

34. *Chenopodium album* Linn. (**3**: 22).

Fairly common on plains, rare on hill. (I. 1658).

35. *Cissampelos pareira* Linn. (**1**: 30).

Large clump at the foot of hill near road, in leaf only.

36. *Clerodendrum phlomidis* Linn. f. (**2**: 225).

Large shrubs, about 3 m. high, masses of flowers; on hedge at foot of hill.

37. *Clitoria ternatea* Linn. (**1**: 230).

Dry plants in leaf and fruit, rare; on plains and lower slopes. The fruits seem rather small for this species.

38. *Cocculus hirsutus* (Linn.) Diels.

C. villosus DC. (**1**: 28).

From the middle of the hill upwards, common; some large plants in fruit (black). (I. 1641).

39. *Corchorus æstuans* Linn.

C. acutangulus Lamk. (**1**: 121).

Dry plants, plenty of fruits; below reservoir, 1 m. high.

40. *Cordia dichotoma* Forst. f.

C. myxa auct., non Linn. (**2**: 82).

Saw several trees, about 8 m. tall, along road near reservoir.

41. *Cordia rothii* R. & S.? (**2**: 85).

Small tree, near top of hill, in leaf only.

42. *Coriandrum sativum* Linn. (**1**: 397).

In cultivated fields, cultivated or escaped; in flower.

43. *Coronopus didymus* (Linn.) Sm.

Senebiera didyma Pers. or *S. pinnatifida* DC.

Common in moist ground, prostrate or suberect, slender herb. (I. 1635). Not mentioned by Duthie.

44. *Dalbergia sissoo* Roxb. (**1**: 264).

About the largest trees in the plains; generally cultivated and often in fruit.

45. *Datura innoxia* Mill.

D. metel auct., non Linn. (**2**: 131).

Shrubby, about 1 m. tall, flowers pure white; along the road near cultivated fields of village.

46. *Daucus carota* Linn. (**1**: 398).

Near the railway line; flowers pinkish; cultivated and escaped.

47. *Dichrostachys cinerea* Wt. & Arn. (**1**: 310).

Small shrubs, only 0·75–3 m. high; on plains near base of hill and on lower slopes.

48. *Dicoma tomentosa* Cass. (**1**: 487).

On the very top and upper slopes, fairly common; small plants only 5–10 cm. high, in fruit and leaf. Rare.

49. *Digera muricata* (Linn.) Mart.

D. arvensis Forsk. (**3**: 8).

Flowers and fruits, rare; saw some plants on bund of cultivated field near village.

50. *Echinops echinatus* Roxb. (**1**: 480).

Along the plains or on the lower slopes of the hill; rather scarce, in fruit.

51. *Elytraria acaulis* (Linn. f.) Lindau.

Tubiflora acaulis in Kuntze (**2**: 180).

The generic name *Elytraria* has been conserved under No. 7908 against the older one, *Tubiflora* (see *Internat. Code Bot. Nomencl.*, 1952, p. 134). A rare plant; seen in bud and leaf under shrubby plants on top of hill; spikes up to 12 cm. long.

52. *Euphorbia hirta* Linn. (**3**: 80).

Common on top of hill, not so common on the slopes, very rare on the plains.

53. *Euphorbia neriifolia* Linn. (**3**: 76).

In leaf; not common; lower part of hill.

54. *Euphorbia thymifolia* Linn. (**3**: 81).

On ground below reservoir, along paths, etc. Abundant, locally in flower and fruit.

55. *Evolvulus alsinoides* Linn. (**2**: 104).

In flower; erect herbs on slopes, in sheltered spots; on rocks on the top of the hill it is prostrate. Fairly common.

56. *Ficus religiosa* Linn. (**3**: 150).

Along the roads at the base of the hill near the reservoir.

57. *Fumaria indica* Pugsl.

F. parviflora Lamk. (**1**: 37).

A weed of cultivated fields; in fields of *Brassica nigra* near station. (I. 1634).

58. *Glossocardia bosvallea* (L. f.) DC.

G. linearifolia Cass. (**1**: 471).

On the upper slopes of hill, in very dry spots. (I. 1647).

59. *Grewia orbiculata* Rottl. (**1**: 115).

Saw several trees on the upper slopes of the hill, in leaf only; identification uncertain.

60. *Grewia damine* Gaertn.

G. salvifolia auct. non Linn. (**1**: 116).

Several trees on slopes, but identification uncertain.

61. *Guazuma tomentosa* H.B.K.

Not in Duthie's Flora; this tree was noted by Prof. R. Misra.

62. *Gymnosporia spinosa* (Forsk.) Fiori.

Celastrus senegalensis Lamk.? (**1**: 159).

I am not satisfied that Lamark's plant is identical with the Indian spiny shrub, hence the name of Lamark has not been adopted. Shrubby, 0·75–4 m. tall, armed with plenty of spines; plenty of fruits on some plants. Common just at the foot of the hill (I. 1650).

63. *Helicteres isora* Linn. (**1**: 102).

On hill slopes, common; some plants in fruit; small shrub.

64. *Heliotropium eichwaldi* Steud. (**2**: 92).

Erect, small herb, with white flowers; typical teeth between the corolla lobes present. Rare. In sandy soil on plains.

65. *Heliotropium indicum* Linn. (**2**: 90).

In flower and leaf, on moist soil near the reservoir.

66. *Hibiscus micranthus* Linn. f. (**1**: 89).

On plains, among spiny shrubs, fairly common, 1–2 m. high; mostly in fruit; flors. fleshy pink, 5–6 mm. diam.

67. *Holoptelea integrifolia* Planch. (**3**: 119).

Planted along roads, large trees, near road leading to reservoir.

68. *Indigofera cordifolia* Heyne (**1**: 250).

Saw several plants in fruit on the higher parts of the hill.

69. *Indigofera trita* Linn. f. (**1**: 252).

On slopes near top of hill, a few plants only.

70. *Ipomœa cairica* (Linn.) Sw.

I. palmata Forsk.

On garden hedge below reservoir, cultivated and running wild; plenty of flowers. Not in Duthie's Flora.

71. *Ipomœa pes-tigridis* Linn. (**2**: 116).

Abundant, but dry, on clumps of *Leptadenia*. etc.; fruits and bracts typical and common.

72. *Ipomœa sindica* Stapf. (**2**: 113).

On plains and lower slopes of hill, rare. Flower and fruit.

73. *Justicia simplex* Don. (**2**: 210).

In open fields, on the plains; flowers rather light in colour; small prostrate plants with erect inflorescence.

74. *Kickxia ramosissima* Janchen.

Linaria ramosissima Wall. (**2**: 140).

Occasional on hill, in flowers and leaves.

75. *Lantana camara* L. var. *aculeata* Mold.

L. camara auct., non Linn. nisi partim. (**2**: 216).

Along hedges in the plains; also near the reservoir; flowers of the paler type; some plants with masses of fruits. Rare on hill. The true *L. camara* Linn. has no spines on stems, etc.

76. *Lantana indica* Roxb. (**2**: 216).

Undershrub with white flowers and unarmed; saw one plant at the foot of the hill.

77. *Lactuca runcinata* DC.? (**1**: 490).

Small plants in leaf only, in open sandy fields at the base of hill.

78. *Lepidagathis trinervis* Wall. (**2**: 204).

On the plains it is a rare plant; on the hill slopes rather common in flower and leaf (I. 1654).

79. *Leptadenia pyrotechnica* (Forsk.) Decne.

L. spartium Wt. (**2**: 63).

Along the plains near the base of the hill this plant is common and abundant, forming large and dense clumps; plenty of flowers and some fruit (I. 1607, 1629).

80. *Lindenbergia indica* (Linn.) O. Kuntze.

L. urticæfolia Lehm. (**2**: 160).

In shaded spots, small plants in flower and leaf. Rare.

81. *Malvastrum tricuspidatum* Gray. (**1**: 79).

Very similar to *Sida*, but flowers larger, yellow; on moist ground below reservoir.

82. *Mangifera indica* Linn. (**1**: 189).

Several large trees near reservoir, obviously cultivated.

83. *Melilotus indica* All. (**1**: 208).

In moist ground below reservoir, flowers yellowish; rare.

84. *Melothria maderaspatana* Cogn. (**1**: 379).

Noticed several plants climbing on spiny clumps on plains; fruits fresh, seeds only 2–3, but typical.

85. *Momordica charantia* Linn. (**1**: 369).

One fresh plant in flower and leaf, on plains; not seen on hill.

86. *Musa paradisiaca* Linn. (**3**: 238).

Cultivated in garden below reservoir.

87. *Nyctanthes arbor-tristis* Linn. (**2**: 24).

In fruit, in garden, near reservoir.

88. *Ocimum americanum* Linn.

O. canum Sims. (**2**: 234).

Abundant on plains near cultivated fields, rare on hill; flowers white, leaves strongly scented. (I. 1656).

89. *Oxalis corniculata* Linn. (**1**: 130).

In moist ground near reservoir. Common herb, rarely in flower.

90. *Pedalium murex* Linn.

Said to be abundant at foot of hill, but I did not see it myself. Not in Duthie's Flora.

91. *Pedilanthus tithymaloides* Poit. (**3**: 116).

Cultivated in garden near reservoir; leaves only.

92. *Pergularia dæmia* (Forsk.) Blatt. & McC.

Dæmia extensa R. Br. (**2**: 52).
In fruit, on plains; rare. (I. 1608).

93. *Peristrophe bicalyculata* Nees. (**2**: 210).

In plains and on lower slopes of hill, in flower and fruit; occasionally mixed with *Andrographis paniculata*, from which it is clearly distinguished by the structure of the corolla.

94. *Polycarpæa corymbosa* Lamk. (**1**: 68).

On plains, in sandy fields; rare.

95. *Polygala erioptera* DC. (**1**: 62).

Flowers purple; fruits present with leaves. Saw in all four specimens, one on plains, others on hill slopes (I. 1644).

96. *Polygonum plebeium* R. Br. (**3**: 31).

Whole plant deep red; plenty of white hairs at the nodes; common on higher parts of hill.

97. *Polygonum barbatum* Linn. (**3**: 36).

Axillary ochrea with large hairs on upper edge; flowers white or nearly so. Common near water below reservoir.

98. *Pupalia lappacea* Juss. (**3**: 19).

Fairly common on plains, dry; on hill slopes, fresh plants.

99. *Ricinus communis* Linn. (**3**: 113).

Cultivated or escape; only seen near cultivated fields.

100. *Rosa* spec.

Cultivated below reservoir; flowers highly scented.

101. *Saccharum spontaneum* Linn.

On plains, along dry ditches, in large clumps. Dry plants.

102. *Salmalia malabarica* Schott. & Endl. ?

Bombax malabaricum DC. (**1**: 98) ?

Among the largest trees along road near reservoir; plenty of leaves, no sign even of buds. Identification probable only.

103. *Salvadora persica* Linn. (**2**: 28).

Noted by Prof. R. Misra; I did not see the tree.

104. *Sericostoma pauciflorum* Stocks.

Not in Duthie's Flora; yet the plant seems to be indigenous to judge from its abundance. Very abundant on plains at the base of hill, forming dense low cushions, often in almost pure. stands (I. 1652).

105. *Sesamum indicum* Linn. (**2**: 175).

Dry plants with remains of fruit, on upper slopes of hill, 50–70 cm. high, unbranched; rare.

106. *Sida grewioides* G.P. & R. (**1**: 81).

Common in flower and fruit; leaves small. Plains near base of hill. (I. 1653).

107. *Solanum nigrum* Linn. (**2**: 124).

Large plants, deep green leaves, white flowers, green fruits; fairly abundant in cultivated field below reservoir.

108. *Sonchus oleraceus* Linn. (**1**: 492).

Below reservoir in moist spots, in flowers; stout plants. (I. 1638).

109. *Spergula arvensis* Linn. (**1**: 67).

In cultivated fields below reservoir. (I. 1637).

110. *Striga euphrasioides* Benth. (**2**: 157).

One plant in flower, several in fruit among grasses on plains and lower slopes.

111. *Tagetes erecta* Linn.? (**1**: 495).

Cultivated in garden near reservoir, in flower.

112. *Tephrosia purpurea* Pers. (**1**: 245).

On top of hill, and on slopes of South side, common and fairly abundant in fruit and leaf.

113. *Tephrosia villosa* Pers. (**1**: 245).

On the lower slopes on South side of hill, clumps of this plant in fruit.

114. *Trianthema decandra* Linn.

T. pentandra auct., non Linn. (**1**: 386).

On bunds of cultivated fields at base of hill; masses of fruits in leaf axils. Rare. (I. 1655).

115. *Tridax procumbens* Linn. (**1**: 475).

In flower and fruit, from the middle to the top of hill, fairly common and abundant.

116. *Trigonella* spec.

Noted by Miss D. Panthaki, B.Sc., in moist ground near reservoir.

117. *Triumfetta bartramia* Linn.?
T. rhomboidea Jacq. (**1**: 118)?
Occasional on plains and hill slopes: 25–60 cm. tall; the size and shape of fruits suggest *bartramia*, though the hairiness at the base of the fruit spines seems somewhat abnormal.

118. *Typha* spec. *elephantina* Roxb.? (**3**: 293).
Large masses in pond below reservoir in flower and fruit.

119. *Urginea indica* Kunth. (**3**: 264).
Bulb collected on hill; only one bulb seen.

120. *Vernonia cinerea* Less. (**1**: 441).
On plains and hill, fairly common; in flower and fruit.

121. *Veronica agrestis* Linn. (**2**: 154).
In moist ground below reservoir, rare; flowers white.

122. *Vicoa indica* (Linn.) DC.
V. auriculata Cass. (**1**: 464).
Flowers yellow; small plant, among *Zizyphus* clumps on plains; occasional on hill.

123. *Wedelia* spec. *wallichii* Less.? (**1**: 470).
Small herb, with yellow flowers; among *Capparis* and other spiny clumps on plains.

124. *Wrightia tinctoria* var. *rothii* Hook.
W. tinctoria R. Br., pro parte. (**2**: 38).
Trees 3-4 m. high, along the road and lower slopes on the further side of the hill. This tree shows a strange mixture of characters of *tinctoria* and *tomentosa*; the fruits are slender, double. as in *tinctoria*; the leaves are strongly pubescent and not acuminate, as in *tomentosa*. Identification certain. (I. 1627).

125. *Xanthium strumarium* Linn. (**1**: 467).
Long dense rows of this plant along the roads in the plains; not seen on hill. Noticed several small donkeys loaded with the fruits abundantly covering their hides.

126. *Zizyphus rotundifolia* Lamk. (**1**: 164).
On plains very common and abundant in almost pure stands, 30–90 cm. high, in dense clumps; occasionally in fruit. This plant is very rare on hill.

127. *Lochnera rosea* (Linn.) Reichenb.
Vinca rosea Linn.
Cultivated in garden below reservoir; flowers only purple, did not see the white-flowered variety.

STUDIES ON INDIAN *PORIA*

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INTRODUCTION

IN the course of studies of wood-rotting fungi in the Herbarium of the Mycology Branch, Forest Research Institute, five species of *Poria* were encountered which have been found to be new records in this country. All the fungi have been collected from the temperate regions of the Himalayas in the divisions of Bashahr (Himachal Pradesh), Chakrata (Uttar Pradesh), Kulu and Seraj (Punjab) between altitudes of 6,000–10,000 feet. Like other Hymenomycetous flora of India, particularly from temperate and sub-tropical regions which are similar to that of temperate regions of Europe and America, these species of *Poria* are also of common occurrence in the U.S.A.

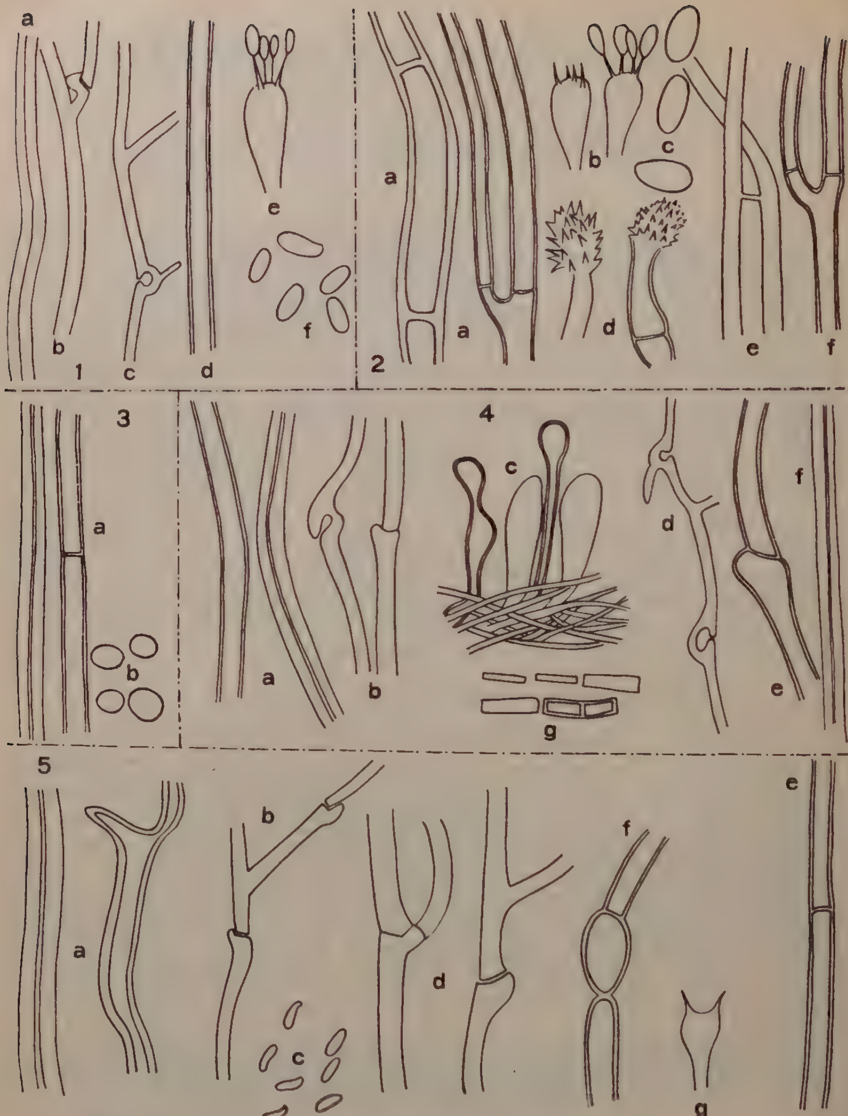
Complete morphological descriptions of these five species and cultural characters of four of them are given. The specimens examined under each fungus are listed along with the host, locality, date of collection and herbarium number (indicated in bold type). The cultures examined are from the National Type Culture Collection of wood-rotting fungi maintained in this laboratory.

Poria callosa (Fr.) Cke. (Pl. XIV, Figs. 1–2)

Sporophore.—Annual, broadly effused, sometimes slightly raised at the margin, coriaceous to corky; margin white, narrow, sterile; subiculum white, less than 1 mm. thick, hyphæ of 2 types: (i) hyaline, thick-walled, aseptate, unbranched (Text-Fig. 1 *a*), abundant, 2·6–3·6 μ broad, (ii) hyaline, thin-walled, branched, septate with clamp connections (Text-Fig. 1 *b*), comparatively rare, 2·5 μ broad; tramal hyphæ similar to hyphæ in the subiculum; pore surface white to 'light buff' becoming 'light ochraceous buff' in older specimens, pore tubes 2–3 mm. long, pores round (Plate XIV, Fig. 2), 3–4 per mm., edges entire; spores hyaline, smooth, cylindric-ellipsoid, 7–9 $\times$ 2–3 μ (Lowe, 1946).

On dead *Picea morinda*, Mundali, Chakrata Division (Uttar Pradesh), June, 1951, **5525**; on logs of *Abies pindrow*, Banjar Range, Seraj Division (Punjab), November 1952, **6097** (*a*), **6099**.

Poria callosa is considered to be the resupinate form of *Trametes serialis* Fr. (Baxter, 1931; Cartwright and Findlay, 1946; Lowe, 1946), which also occurs in the Himalayas and both the species agree in their cultural characters. Interfertility tests were made between monospore cultures of *P. callosa* and *T. serialis* resulting in the formation of clamp-connections which confirm that they belong to the same species. Both *P. callosa* and *T. serialis* are widespread in the temperate Himalayas, and also of common occurrence in America and Europe.



TEXT-FIGS. 1–5. Fig. 1. *Poria callosa.* (*a*) thick-walled hypha from subiculum, (*b*) thin-walled hypha from the subiculum, (*c*) hypha from advancing zone of culture, (*d*) thick-walled hypha in culture, (*e*) basidium in culture, (*f*) basidiospores in culture, ×938. Fig. 2. *Poria corticola.* (*a*) thick-walled hyphæ from subiculum, (*b*) basidia, (*c*) basidiospores, (*d*) capitate cystidia, (*e*) thin-walled hypha and (*f*) thick-walled hypha in culture, ×938. Fig. 3. *Poria nigrescens.* (*a*) thick-walled hyphæ from the subiculum, (*b*) basidiospores, ×938. Fig. 4. *Poria versipora.* (*a*) thick-walled hyphæ from subiculum, (*b*) thin-walled hyphæ from subiculum, (*c*) terminally inflated hyphæ in the hymenium, (*d*) thin-walled hyphæ from advancing zone of culture, (*e*) hypha from aerial mycelium, (*f*) thick-walled hypha in culture, (*g*) oidia, ×938. Fig. 5. *Poria xantha.* (*a*) thick-walled hyphæ from subiculum, (*b*) thin-walled hyphæ from subiculum, (*c*) basidiospores, (*d*) thin-walled hyphæ in culture, (*e*) thick-walled hypha in culture, (*f*) chlamydospore, (*g*) basidium in culture, ×938.

Rot.—The fungus causes a brown cuboidal rot on conifers (Plate XIV, Fig. 1 *b*).

Cultural characters

Growth characters.—Growth slow, optimum between 23–25° C. (1·7 cm.), inhibiting at about 33–35° C. Advancing zone hyaline, appressed, abruptly changing to white. Mat white, appressed, felty, becoming pitted and corrugated to form an irregularly pored surface (2–4 weeks) practically extending over the whole of the mat. On gallic and tannic acid agars,* no diffusion zones, growth† 0·7 cm. each. On gentian violet agar growth good, media not discoloured.

Hyphal characters (Advancing zone).—Hyphæ hyaline, branched, septate with clamp-connections (Text-Fig. 1 *c*), 1·4–4·3 μ broad. Aerial mycelium: (i) hyphæ as in advancing zone; (ii) hyaline, thick-walled, unbranched, aseptate (Text-Fig. 1 *d*), 1·4–2·9 μ broad; (iii) Fruit-body: hyphæ as above, basidia clavate (Text-Fig. 1 *e*), 4·3–5·7 μ broad with 4 sterigmata bearing 4 basidiospores; basidiospores hyaline, thin-walled, smooth, fusiform-elliptical or ellipsoid-cylindric (Text-Fig. 1 *f*), 4·2–6·3 × 1·7–2·4 μ. Submerged mycelium: hyphæ as in advancing zone.

Cultures examined. 207 (*a*)/K; 68–T; 194/K.

Poria corticola (Fr.) Cke. (Plate XIV, Fig. 3)

Sporophore.—Annual, completely resupinate, inseparable, soft-leathery when dry; subiculum very thin, inconspicuous, white, hyphæ of the subiculum hyaline to 'light buff' under the microscope, thick-walled, branched with abundant septa, clamp connections absent (Text-Fig. 2 *a*), 2·6–5·7 μ broad; tramal hyphæ similar to those in the subiculum; pore surface 'pale ochraceous buff', 'light ochraceous buff', or a shade darker, dull, tubes up to 2 mm. long, pores round to angular or irregular (Plate XIV, Fig. 3), averaging 2–4 per mm., edges thin, fimbriate sometimes lacerate; basidia clavate (Text-Fig. 2 *b*), 5·0–6·5 μ broad; basidiospores hyaline, smooth, ellipsoid (Text-Fig. 2 *c*), 6·1–7 × 3·6–4 μ; cystidia conspicuous, abundant, capitate, elongate (Text-Fig. 2 *d*), diameter of the head up to 9·3 μ, also present in the sub-hymenium.

On a log of *Abies pindrow*, Banjar Range, Seraj Division (Punjab), November, 1952, **6097**.

The fungus is reported to be common in the U.S.A. on broad-leaved hosts like species of *Acer*, *Fagus*, *Populus*, etc. (Baxter, 1935; Lowe, 1946; Overholts, 1923), though the fungus is also recorded on *Thuja plicata* (Overholts, 1929) and fir (Rea, 1922).

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* The tests laid down by Bavendam (1928), Preston and McLennan (1948) were followed for distinguishing lignin and cellulose destroying fungi in culture. Colours described within commas are from Ridgway (1912).

† Growth in all cases represents radial growth in 7 days at 25° C. unless otherwise stated.

Rot.—The fungus causes a white fibrous rot.

Cultural characters

Growth characters.—Growth moderately rapid, optimum between 20–22° C. (2 cm.), inhibiting at about 36–38° C. Advancing zone white, growth unequal around the inoculum, aerial mycelium extending up to limit of growth. Mat white, cottony-woolly, later becoming prostrate and felty except near the periphery where it is thick woolly and rolls over the walls of the Petri dish, faintly zonate. Reverse bleached. On gallic acid agar, diffusion zones weak, growth none; on tannic acid agar diffusion zones moderately strong, growth 0·7 cm. On gentian violet agar growth weak, media not discoloured.

Hyphal characters (Advancing zone).—Hyphæ hyaline, thin-walled, branched with simple septa (Text-Fig. 2 *e*), 1·5–4·3 μ broad. Aerial mycelium: hyphæ as in advancing zone, also slightly thick-walled (Text-Fig. 2 *f*), 2·9–4·3 μ broad. Submerged mycelium: hyphæ as in aerial mycelium, up to 5·8 μ broad.

Culture examined. 207/K.

Poria nigrescens Bres. (Plate XIV, Fig. 4)

Sporophore.—Annual, completely resupinate, hard, brittle on drying, separable; margin thin to thick becoming involute on drying, matted; subiculum up to 1 mm. thick, 'light ochraceous buff', hyphæ of the subiculum hyaline ('light buff' under the microscope), thick-walled with narrow lumen, apparently unbranched, septate (Text-Fig. 3 *a*) but septa very rare and difficult to demonstrate, 2·0–5·4 μ broad, thinner few; tramal hyphæ same as subiculum hyphæ; pore surface 'pale olive buff', 'tilleul-buff', 'pale pinkish buff' with patches of 'avellaneous' turning darker at the margin, tubes 'light ochraceous salmon', up to 4 mm. long, pores round to angular, 5–8 per mm.; basidiospores hyaline, smooth, thin-walled, sub-globose (Text-Fig. 3 *b*), $3{\cdot}5\text{–}5{\cdot}6 \times 2{\cdot}8\text{–}4{\cdot}3\ \mu$.

On a log of *Quercus incana*, Mundali, Chakrata Division (Uttar Pradesh), September, 1949, **5369**.

The specimen on which the above description is based is an annual plant. *P. nigrescens* is, however, perennial (Baxter, 1931; Lowe, 1946; Overholts, 1922), the annual form of which is *Poria undata* (Pers.) Bres. (Lowe, 1946). Cunningham (1947) and Murrill (1921) also consider *P. nigrescens* and *P. undata* as synonyms. It is preferred to name our specimen as *P. nigrescens* since it was described earlier by Bresadola in 1897. Further, the specimen has been compared with an American specimen of the species, identified by D. V. Baxter (No. 5600) and is identical with it in all characters, though the American specimen is somewhat thicker.

The fungus is reported to be quite common on wood of deciduous or rarely of coniferous trees in the U.S.A. right up to Alaska (Lowe, 1946) and has also been reported from England and Europe (Murrill, 1921).

Rot.—The fungus is associated with a white rot.

Poria versipora (Pers.) Rom. (Plate XIV, Figs. 5 and 6)

Sporophore.—Annual, broadly effused, corky, brittle when dry; margin white to 'pale ochraceous buff', narrow to wide—non-porous in the latter case; subiculum 'pale ochraceous buff' to 'pinkish buff' less than 1 mm. thick, hyphæ of two types: (i) hyaline, thick-walled, apparently aseptate, unbranched or rarely branched (Text-Fig. 4 *a*), $3 \cdot 0$–$4 \cdot 3\,\mu$ broad, (ii) hyaline, thin-walled, sparsely branched, septate with clamp connections (Text-Fig. 4 *b*), up to $2 \cdot 7\,\mu$ broad; trama continuous with the subiculum, tramal hyphæ same as subiculum hyphæ; pore surface 'pale ochraceous buff', 'light ochraceous buff', 'pinkish buff', 'cinnamon buff', pore tubes up to $1 \cdot 5$ mm. long, pores round, oblong or angular, lamellate on sloping surface (Plate XIV, Fig. 6), 4–6 per mm., edges entire or lacerate, pore surface irpiciform in certain areas; basidia clavate, 3–4 μ broad (Baxter, 1939; Lowe, 1946), basidiospores hyaline, smooth, oblong-ellipsoid to ellipsoid, 4–5 $(-7) \times 2$–5–$3 \cdot 5$ $(-4)\,\mu$ (Baxter, 1939; Cunningham, 1947; Lowe, 1946), small cystidia-like structures infrequently present in the hymenium; thick-walled terminally-inflated hyphæ projecting slightly beyond the hymenium (Text-Fig. 4 *c*).

On a log of *Celtis australis*, Kasol, Parbatti Range, Kulu Division (Punjab), October, 1952, M. **797**, **6021**.

Though no basidia and basidiospores have been observed in the specimens examined, other characters like the habit, colour of the pore surface, subiculum and subicular hyphæ, presence of cystidia-like structures, and terminally inflated hyphæ in the hymenium, the rot produced by the fungus, etc., agree with *Poria versipora.*

Rot.—The fungus causes a white rot of hardwood species.

Cultural characters

Growth characters.—Growth moderately rapid, optimum between 20–22° C. ($2 \cdot 5$ cm.), inhibiting at about 32–33° C. Advancing zone white, raised, even, aerial mycelium extending to limit of growth. Mat white, raised woolly with somewhat farinaceous appearance, particularly around the inoculum, later becoming loosely appressed, sub-felty. Reverse partially bleached. On gallic and tannic acid agars diffusion zones weak, growth nil and $2 \cdot 2$ cm. respectively. On gentian violet agar growth good, medium discoloured.

Hyphal characters.—Advancing zone: hyphæ hyaline, thin-walled, branched, septate with clamp connections (Text-Fig. 4 *d*), $1 \cdot 2$–$4 \cdot 4\,\mu$ broad. Aerial mycelium: (i) hyphæ hyaline, thin-walled or slightly thick-walled with clamp connections (Text-Fig. 4 *e*) as in advancing zone; (ii) hyphæ hyaline, thick-walled, unbranched, aseptate (Text-Fig. 4 *f*), $2 \cdot 5$–$3 \cdot 1\,\mu$ broad; (iii) oidia scanty, 1–2-celled (Text-Fig. 4 *g*), $7 \cdot 3$–$11 \cdot 6 \times 1 \cdot 5$–$2 \cdot 2\,\mu$. Submerged mycelium: hyphæ same as in advancing zone.

Culture examined. 27/K.

Poria xantha (Fr.) Cke. (Plate XIV, Figs. 7 and 8)

Sporophore.—Annual, broadly effused, not readily separable, brittle when dry; margin white to 'pale pinkish buff', sterile or pores extending up to the edge, pubescent, thin to thick; subiculum white, thin, less than 1 mm. thick, hyphæ of the subiculum of two types: (i) hyaline to 'light buff', thick-walled, aseptate, rarely branched (Text-Fig. 5 *a*), $2 \cdot 9$–$5 \cdot 6\,\mu$ broad, (ii) hyaline, thin-walled, branched, septate with clamp connections (Text-Fig. 5 *b*), $1 \cdot 2$–$2 \cdot 3\,\mu$ broad, the two types compactly interwoven; tramal hyphæ similar to hyphæ of the subiculum; pore surface 'cream colour', 'ivory yellow', 'straw yellow', often exhibiting cracks, pore surface chalky, pore tubes up to 4 mm. long, pores round (Plate XIV, Fig. 8), averaging 5–6 per mm.; basidia clavate or cylinderaceous, $4 \cdot 2\,\mu$ broad; basidiospores hyaline, smooth, cylinderaceous, slightly allantoid (not strongly curved) (Text-Fig. 5 *c*), $3 \cdot 6$–$4 \cdot 3 \times 1 \cdot 1$–$1 \cdot 4\,\mu$.

On a charred log of *Pinus excelsa*, Toshnal, Kulu Division (Punjab), October, 1940, **3211**, **3212**, Pulga, Kulu Division (Punjab), October, 1952, **6064**, Toshnal, Kulu Division (Punjab), October, 1952, **6028**, M. **802**; on logs of *Pinus excelsa*, Narkanda, Lower Bashahr Division (Himachal Pradesh), June, 1946, **4406**, **4423**, Bandal, Banjar Range, Seraj Division (Punjab), November 1952, **6016**, Jibbi, Banjar Range, Seraj Division (Punjab), November, 1952, **6115**, Pulga, Kulu Division (Punjab), October, 1952, **6022**; on log of *Quercus semecarpifolia*, Soja, Banjar Range, Seraj Division (Punjab), November 1952, **6204**, M. **808**.

The fungus is world-wide in distribution and has been reported from America, England, Europe and New Zealand. In the former two countries it is common as house rot on building timber and also causes decay in wooden boats (Boyce, 1948; Cunningham, 1947). The fungus is quite common in the coniferous forests of the temperate Himalyas where it has been frequently encountered. It has often been found growing on charred logs and stumps.

Rot.—The fungus causes a brown cuboidal rot, usually of conifers and less commonly of hardwood species (Plate XIV, Fig. 7 *b*).

Cultural characters

Growth characters.—Growth moderately rapid, optimum between 30–31° C. ($2 \cdot 9$ cm.), inhibiting at 40° C. Advancing zone hyaline, completely appressed, even. Mat hyaline, appressed. Aerial mycelium lacking or limited to a thin film, surface becoming minutely poroid away from the inoculum after two weeks. Reverse unchanged. On gallic and tannic acid agars, no diffusion zones, growth $0 \cdot 5$ and $0 \cdot 1$ cm. respectively. On gentian violet agar growth good, medium not discoloured.

Hyphal characters.—Advancing zone: hyphæ hyaline, thin-walled, branched, septate with clamp connections, $1 \cdot 6$–$5 \cdot 8\,\mu$ broad. Aerial mycelium: (i) hyphæ hyaline, thin-walled to slightly thick-walled, branched, septate with clamp connections (branches also arising from

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the clamps) (Text-Fig. 5 *d*), 1·6–5·8 μ broad, (ii) hyaline, thick-walled, non-staining segments of hyphæ, clamp connections comparatively less (Text-Fig. 5 *e*); (iii) chlamydospores present though rare, usually intercalary, rarely terminal, walls slightly thickened (Text-Fig. 5 *f*), 11·4–15·8 × 5·7–7·0 μ; (iv) Fruit body composed of thin-walled hyaline, hyphæ with clamp connections, interwoven with non-staining fibre hyphæ, basidia 3·7 μ broad (Text-Fig. 5 *g*), bearing 4 spores; basidiospores hyaline, smooth, cylinderaceous, slightly allantoid, 3·6–4·3 (– 5·3) × 1·1–1·4 μ.

Cultures examined. 62/K; 86/K; 149/K; 177/K; 197/K.

Acknowledgements

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Explanation of Plate

Plate XIV

Fig. 1 (*a*) *Poria callosa.*—Sporophore growing on wood of *Abies pindrow*, ×0·21.
(*b*) Brown cuboidal rot caused by *P. callosa*, ×0·21.

Fig. 2. *Poria callosa.*—A view of the pore surface, ×1·0.

Fig. 3. *Poria corticola.*—A view of the pore surface, ×1·0.

Fig. 4. *Poria nigrescens.*—A sporophore, ×0·47.

Fig. 5. *Poria versipora.*—Sporophore growing on log of *Celtis australis*, ×0·30.

Fig. 6. *Poria versipora.*—A view of the pore surface, ×1·0.

Fig. 7 (*a*) *Poria xantha.*—Sporophore growing on a log of *Pinus excelsa*, ×0·33.
(*b*) Brown cuboidal rot caused by *P. xantha*, ×0·33.

Fig. 8. *Poria xantha.*—A view of the pore surface, ×1·0.

FOSSIL WOODS OF EUPHORBIACEAE FROM THE TERTIARY ROCKS OF SOUTH ARCOT DISTRICT, MADRAS

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Introduction

The present paper deals with three new genera of fossil woods of Euphorbiaceæ collected from the Tertiary rocks of Mortandra, five miles North-West of Pondicherry in the South Arcot District. A brief description of two of these woods has already been published in the form of a short note (Ramanujam, 1954 *a*). The fossiliferous locality has so far yielded a tolerably rich collection of interesting petrified woods of angiosperms. From the same locality the writer has previously reported the occurrence of fossil woods resembling the modern genera *Mangifera*, *Shorea* and *Albizzia* (Ramanujam, 1953), and described in detail the wood anatomy of two leguminous woods comparable with the modern genera *Acacia* and *Cæsalpinia*, and three species of Dipterocarpaceæ resembling the extant species of *Dipterocarpus* and *Shorea* (Ramanujam, 1954 *b*, 1955). Again very recently two new species of fossil woods of *Terminalia* have been described from the same locality (Ramanujam, 1956).

As far as is known to the writer no fossil woods of Euphorbiaceæ have been described hitherto from the Indian horizons. Even from outside India the reports of fossil woods of Euphorbiaceæ are few and far between. They are known to occur, however, in the Cretaceous of Arizona (Bailey, 1924), Tertiary of Columbia (Felix, 1887), East Africa (Bancroft, 1932), Kiushu and Tobata. Japan (Ogura, 1933, Watari, 1943), Algeria (Boureau, 1951), and Eocene of Eden Valley, Wyoming (Kruse, 1954).

The preservation of all the fossils is sufficiently good to make possible the study of the significant details of their anatomical structures, and consequently their affinities with the modern timbers. Several transverse, tangential and radial sections were made of each wood. The sections usually tend to become extremely transparent when mounted in Canada balsam. consequently they had to be examined under glycerine in reflected light. Comparisons were made as far as possible with the modern timbers.

Putranjivoxylon nov. gen.

Putranjivoxylon puratanam nov. sp.

The material consists of a small block of highly silicified wood which has a variegated colour ranging from white to yellow with

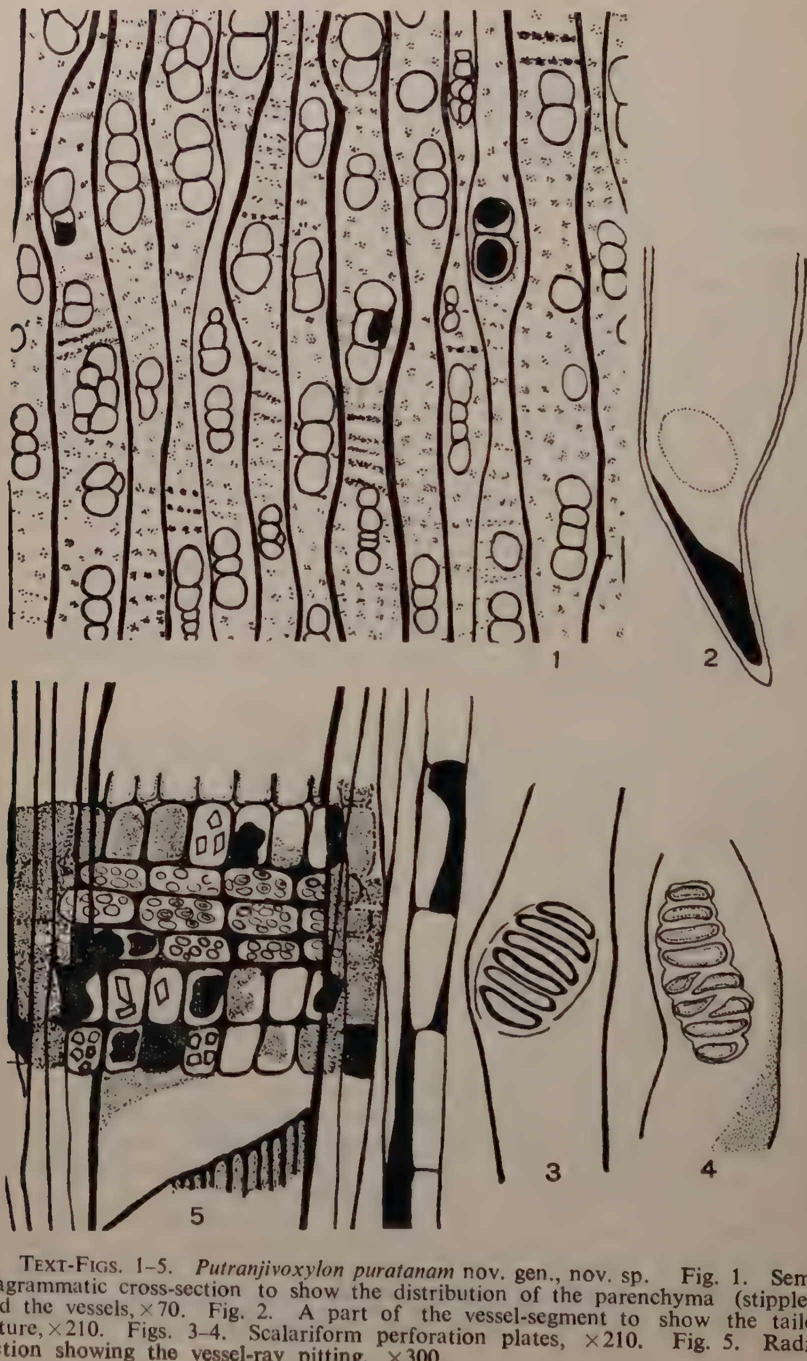
brick-red patches here and there. The preservation of the fossil is very satisfactory.

The fossil does not show any growth rings either to the naked eye or under the microscope. The vessels are moderately thick-walled, mostly small, sometimes medium and are not visible to the naked eye; but with a hand-lens they can be seen as light-coloured dots against the general background of the wood. The vessels are evenly distributed without showing any distinct pattern. They are frequently with contiguous rays on one or both sides. The vessel-segments are short, truncate or abruptly or frequently attenuately tailed on one or both ends (Text-Fig. 2). The vessels usually occur in radial multiples of 2–5 (Plate XV, Fig. 2). Solitary vessels are as a rule quite few and oval to rounded in outlines; those in the radial multiples are flattened often extremely so at the places of contact. The vessels are either empty or plugged with a brown-coloured deposit which either completely occludes the vessel cavities or occurs only in the form of a parietal layer. The fossil does not show any tylosic ingrowths. The perforations are simple or often scalariform (Text-Figs. 3, 4; Plate XV, Figs. 3, 4). The scalariform perforations are formed usually of 4–8 considerably thick scalariform bars, and are either vertical or oblique. The scalariform bars are either entire or broken. The simple perforations are horizontal or slightly inclined. The intervessel pitting is abundant; the pits, however, are very small, bordered and alternate. They are usually circular with oval to elliptical apertures. The vessel-ray pits are simple or bordered, large, rounded or slightly elongated tangentially and many per cell (Text-Fig. 5).

The fibres are libriform and well preserved. They are squarish to polygonal and distributed in radial seriations when seen in transverse sections, frequently interrupted by the cells of the apotracheal parenchyma. They are long and typically aseptate. Pitting of the fibres can be seen here and there in tangential sections. The pits, however, are very small, simple, and oval to rounded in outline (Text-Fig. 6); they generally tend to be arranged in a linear manner.

The parenchyma despite being fairly abundant cannot be seen easily with the naked eye or a hand-lens on the polished transverse surface of the fossil. Under the microscope the parenchyma is found to be well preserved. It is wholly apotracheal and occurs principally in the form of numerous scattered cells or small groups of cells (Text-Fig. 1; Pl. XV, Figs. 1, 2). Frequently the parenchyma cells are arranged in very short, uniseriate rows, which tend to form an extremely fine, more or less irregular reticulum with the wood rays. These rows of parenchyma are, usually rather widely spaced, but at times several of them may be found close together radially. The parenchyma cells are either empty or filled with an yellowish-brown gummy deposit. They are rounded or angular in transverse section. Pits to the parenchyma seen in tangential sections are simple, small, round to oval and 4–10 per cell.

The xylem rays are numerous and somewhat closely arranged. Their outlines are quite distinct to the unaided eye. With a hand-lens



TEXT-FIGS. 1–5. *Putranjivoxylon puratanam* nov. gen., nov. sp. Fig. 1. Semi-diagrammatic cross-section to show the distribution of the parenchyma (stippled) and the vessels, ×70. Fig. 2. A part of the vessel-segment to show the tailed nature, ×210. Figs. 3–4. Scalariform perforation plates, ×210. Fig. 5. Radial section showing the vessel-ray pitting, ×300.

they are visible on the transverse surface of the fossil as fine lines, often deflected by the vessels. The form and the nature of the rays as seen in tangential and radial sections provide valuable information regarding the affinity of the fossil. The rays as a rule are narrow, being only 1–3 cells wide and are 10–60 cells high (Pl. XV, Figs. 5, 6). Most of the rays are markedly heterogeneous.

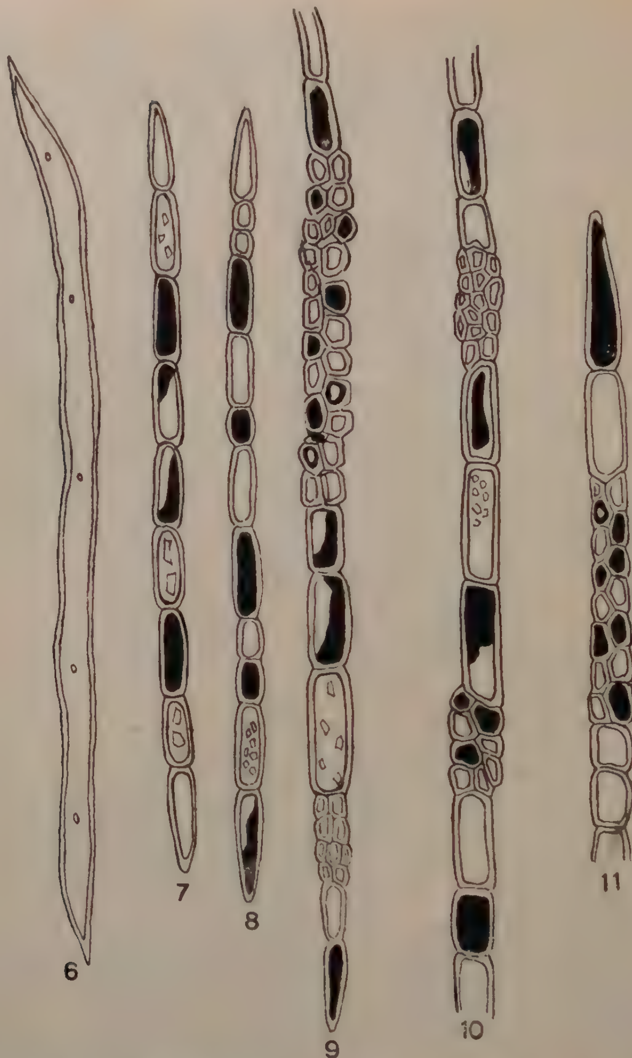
The multiseriate parts are limited to relatively small portions of each ray. These multiseriate portions are made up entirely of small procumbent cells, and alternate with the uniseriate parts formed of vertical cells. The rays can be distinguished into four distinct types: (1) uniseriate rays with vertical cells only (Text-Fig. 7; Pl. XV, Fig. 5); (2) uniseriate rays with alternate vertical and procumbent cells (Text-Fig. 8); (3) rays with alternating multiseriate small procumbent cells and uniseriate vertical cells (Text-Figs. 9, 10); and (4) rays with multiseriate small procumbent cells in the middle and uniseriate vertical cells (2–8 rows) at the margins (Text-Fig. 11). The markedly heterogeneous nature of the rays can be seen clearly in radial sections also (Pl. XV, Fig. 7). The ray cells in general are considerably thick-walled and crystalliferous; sometimes the ray cells are plugged with a dark brown substance of unknown nature which masks the crystals. Pits to the tangential walls of the rays are not observed.

Comparison with the living species.—The diagnostic features of this fossil wood that help in finding out its affinities are: (1) vessels small, arranged in radial multiples of 2–5, (2) perforations simple or often scalariform, (3) parenchyma, diffuse, in the form of numerous scattered cells or cell groups, also frequently in very short uniseriate rows, (4) rays markedly heterogeneous, considerably high, 1–3 seriate, with the multiseriate portions usually limited to relatively small portions of each ray; ray cells crystalliferous. A comparison with the modern woods has shown that the fossil approaches some genera of families like Cunoniaceæ, Sterculiaceæ, Sapotaceæ, Ebenaceæ, and Euphorbiaceæ more or less closely.

In Cunoniaceæ species of *Geissois* (Dadswell and Eckersley, 1938) present many similarities with our fossil in the general wood structure. Significant differences are there, however, in some minute details. Thus in the species of *Geissois* scalariform perforations are sporadic, fibres possess bordered pits with slit-like apertures, and the xylem rays are 1–4 seriate with the vertical cells present only on the margins.

In Sterculiaceæ species of *Pterospermum* show some strong similarities to our fossil in the general anatomy of the wood, but differ in possessing exclusively simple perforations, and storied nature of parenchyma (Chattaway, 1937).

In the family Sapotaceæ the genus, *Madhuca latifolia* (syn. *Bassia latifolia*) shows several similarities to our fossil. In both, the vessels are small and arranged in radial groups of 2–5, the parenchyma is diffuse or in short uniseriate rows, and the rays are 1–3 seriate, and markedly heterogeneous. But, there are also several differences.



TEXT-FIGS. 6–11. *Putranjivoxylon puratanam* nov. gen., nov. sp. Fig. 6. A libriform fibre showing the pitting, ×300. Fig. 7. Uniseriate ray with entirely vertical cells, ×210. Fig. 8. Uniseriate ray with vertical cells and procumbent cells, ×210. Figs. 9–10. Multiseriate rays with alternating patches of procumbent and vertical cells, ×210. Fig. 11. A biseriate rays with marginal vertical cells, ×210.

Thus in *Madhuca latifolia* the radial groups of the vessels are frequently disposed in oblique rows, vasicentric tracheids are common, scalariform perforations are conspicuous by their absence, and lastly the rays do not show alternating patches of procumbent and vertical cells, a characteristic feature of our fossil.

In the family Ebenaceæ the woods of some species of *Diospyros*, *viz.*, *Diospyros melanoxylon*, *D. ebenum*, and *D. montana* show resemblance to the South Indian fossil in the size, shape and arrangement of the vessels and in the distribution of the parenchyma. But in other features there are marked differences. Thus in the above species of *Diospyros* growth rings are fairly distinct, the perforations are exclusively simple, and the fibres possess distinct bordered pits, and the rays although narrow and heterogeneous do not contain intermittent multiseriate patches of procumbent cells.

Euphorbiaceæ is a markedly heterogeneous family. It is divided into two major sections based on wood anatomy (Janssonius, 1929; Soleredor, 1908; Metcalfe and Chalk, 1950), (1) Phyllanthoideæ and (2) Crotonoideæ. The Phyllanthoideæ is again divided into two groups, *Aporosa* and *Glochidion*. The *Aporosa* type is characterised by the following characters: Vessels often with scalariform perforation plates, intervessel pitting small to minute, pits to ray cells elongated and large. Parenchyma abundant, diffuse, strands of 8–16 cells. Rays of 2 sizes, considerably broad, several millimetres high, markedly heterogeneous, often with more than 10 marginal rows of upright cells. Fibres long, with very thick walls and simple pits.

The *Glochidion* type shows: vessels with simple perforations, intervessel pitting minute to large, pits to ray cells elongated and large or round and small. Parenchyma absent or as rare cells about the vessels. Rays sometimes of 2 distinct sizes, up to 3–11 cells wide; heterogeneous, sometimes markedly so. Fibres medium to long, septate, with simple pits.

The *Crotonoideæ* section is characterized by the following features: Vessels with simple perforations, intervessel pitting typically medium to large, pits to ray cells either large and elongated or similar to the intervessel pitting. Parenchyma abundant, apotracheal, varying from scattered cells to continuous tangential bands, sometimes with a little paratracheal addition. Rays exclusively uniseriate, or 2–3 cells wide, markedly heterogeneous. Fibres short to medium, commonly aseptate with simple pits (Metcalfe and Chalk, 1950, Vol. 2, pp. 1208–09).

The combination of the anatomical features exhibited by the South Indian fossil wood indicates in no uncertain manner a definite relation with the wood of the *Aporosa* type of the family Euphorbiaceæ. A comparison of the South Indian fossil with the various members of the *Aporosa* type has revealed that it resembles closely two genera, *Putranjiva* and *Drypetes*. (According to Metcalfe and Chalk, 1950, the genera *Putranjiva* and *Drypetes* can be very easily fitted into *Aporosa* group than elsewhere.) Both *Putranjiva* and *Drypetes*, resemble each other more or less closely in their wood anatomy. *Drypetes* is represented by about six species in India. *Putranjiva* is represented in India by two species, *Putranjiva roxburghii*, and *Putranjiva zeylanica*, the first of which is very common both wild and in cultivation. The author has compared the fossil wood with both these species of *Putranjiva* and also with the species of *Drypetes*, *viz.*, *D. longifolia*, etc.. It is with the wood type of

Putranjiva that the South Indian fossil agrees most closely. The resemblance occurs in all the major anatomical features. In the genus *Drypetes* scalariform perforations are generally rare, the parenchyma is more definitely banded and the vessels are more commonly solitary. *Drypetes longifolia* differs from the fossil in possessing only simple perforations, mostly solitary vessels, and in ray cells which are only occasionally crystalliferous.

Comparison with the fossil species.—Only a few fossil woods of the family Euphorbiaceæ are known. They are, *Euphorbioxylon speciosum* (Felix, 1887) from Columbia, *Paraphyllanthoxylon arizonense* (Bailey, 1924) from Arizona, *Dryoxylon drypeteoides* (Bancroft, 1932) from East Africa, *Phyllanthinium pseudo-hobashiraishi* (Ogura, 1933, Watari, 1943) from Kiushu and Tobata, Japan, *Euphorbioxylon lafrancii* (Boureau, 1951) from Algeria, and *Haveoxylon microporosum* (Kruse, 1954) from the Eocene of Eden Valley, Wyoming. All these except *Paraphyllanthoxylon arizonense* are of Tertiary age. *P. arizonense* was described from the Cretaceous of Arizona.

All these species differ more or less markedly from the South Indian wood. Thus *Euphorbioxylon speciosum* differs from the present specimen in the possession of vasicentric parenchyma, relatively short rays which are only weakly heterogeneous, and in lacking scalariform perforations. *Paraphyllanthoxylon arizonense* is characterized by much broader rays (1–7 seriate), exclusively simple perforations, and the absence of wood parenchyma.

Of the fossil woods of Euphorbiaceæ hitherto described only one species, *Dryoxylon drypeteoides* (Bancroft, 1932) from the Tertiary of East Africa, shows some close resemblance to our fossil. This wood is, however, very imperfectly preserved and Bancroft could give the description of only its transverse sections. Consequently our fossil cannot be compared with the East African species in all its details. The parenchyma in *Dryoxylon drypeteoides* is like that in our fossil, *i.e.*, occurring in uniseriate rows or scattered cells. But in Bancroft's species the parenchyma bands are more definite and numerous, and more closely set. In *Dryoxylon drypeteoides* radial multiples of more than 2 or 3 vessels are only occasionally seen. As the longitudinal sections of *Dryoxylon drypeteoides* were not described, we know nothing regarding the nature of the perforations and the structural details of the rays of that wood.

Our fossil also differs from Ogura's *Phyllanthinium pseudo-hobashiraishi* in more than one respect. Thus, in the latter species the fibres are fusiform, xylem parenchyma is scanty, the rays are shorter and the perforations are exclusively simple.

Euphorbioxylon lefrancii (Boureau, 1951) which according to its author resembles closely the genus *Anthostema* of the section *Crotonoideæ*, is easily distinguishable from the South Indian fossil in possessing only simple perforations, very scanty parenchyma and mostly uniseriate rays.

Haveoxylon microporosum (Kruse, 1954) differs from our species in possessing exclusively simple perforations, abundantly tylosed vessels, and irregular multiseriate bands of metatracheal parenchyma. Moreover, rays in *Haveoxylon microporosum* are only 1–2 seriate with uniseriate and biseriate patches regularly alternating with each other.

For detailed comparisons, reference may be made to the table at the end.

Name of the fossil and diagnosis.—A comparison of the fossil with the living species has shown that its nearest affinity is with the timbers of Euphorbiaceæ. Felix (1887) after discussing the affinities of his fossil wood, from the Tertiary of Columbia, named it as *Euphorbioxylon speciosum*. The name *Euphorbioxylon* if adopted would naturally include all the fossil woods showing similarities with any member of the Euphorbiaceæ. But it is an established fact that Euphorbiaceæ is not a homogeneous family so far as its wood anatomy is considered (Soleredor, 1908; Record and Mell, 1924; Jansonnius, 1929; Metcalfe and Chalk, 1950). Bailey (1924) says: "To attempt to include all putative Euphorbiaceous woods in a single form genus, *e.g.*, *Euphorbioxylon*, would be unfortunate. The Euphorbiaceæ structurally are an extremely heterogeneous group. So many different stages in the specialization of the vascular tissues are represented that there appear to be no diagnostic characters which are constant in the family as a whole." Felix compared his *Euphorbioxylon* with the woods of *Jatropha* and *Euphorbia* and therefore his diagnosis of the genus *Euphorbioxylon* includes the characters of these genera which fall on the basis of their wood anatomy, in the section *Crotonoideæ*. It is, therefore, evident that the genus *Euphorbioxylon* cannot be employed in a wide sense to include the woods of Euphorbiaceæ as a whole. In fact, it would be extremely difficult to define the limits of *Euphorbioxylon* if all the structural variations of the family Euphorbiaceæ were to be incorporated in it. Since our specimen shows a very strong resemblance with the modern genus *Putranjiva* it is being described here under a new generic name *Putranjivoxylon*. It is specifically named as *Putranjivoxylon puratanam*, the word *puratanam* being derived from the Sanskrit root *puratan*, meaning ancient.

In the present-day flora of India species of *Putranjiva* (especially *Putranjiva roxburghii*) have a wide distribution being found in South India, Deccan peninsula, Western Ghats, Orissa, and Uttar Pradesh (Hooker, 1885; Gamble, 1922).

Putranjivoxylon nov. gen.

A diffuse porous wood.

Growth rings absent.

Vessels mostly small, sometimes medium, hardly visible to the naked eye; mostly in radial multiples of 2–5, solitary vessels few; thick-walled, oval to round; tyloses absent; vessel-segments short, truncate, or abruptly or attenuately tailed; perforations simple, often

scalariform, horizontal or oblique; intervessel pits small, alternate, circular with oval to elliptical apertures. vessel-ray pits large, simple, or bordered, rounded or elongated tangentially and many per cell.

Fibres long, libriform square to polygonal in cross-section, arranged regularly in undisturbed radial seriations; aseptate; pits very small, simple, oval.

Parenchyma fairly abundant; wholly apotracheal, either in the form of numerous closely scattered cells or cell groups, or as very short uniseriate lines of 3–5 cells; parenchyma cells rounded or angular in cross-section, empty; pits simple, small round to oval, 4–10 per cell.

Rays numerous, closely spaced; evenly distributed; markedly heterogeneous with 2–8 marginal rows of vertical cells, 1–3 seriate, 10–60 cells high; uniseriate rays made up either entirely of vertical cells or alternating vertical and procumbent cells; in multiseriate rays multiseriate portions short, formed wholly of procumbent cells, such multiseriate parts alternating with portions formed of vertical cells in a single row; ray cells thick-walled, abundantly crystalliferous.

Putranjivoxylon puratanam nov. sp.

Vessels 75–120 μ in diameter; evenly distributed 25 per sq. mm.; in radial multiples of 2–5, thick-walled and without tyloses, vessel-segments 150–550 μ long, perforations simple or often scalariform, with 4–8 thick perforation bars.

Fibres 150–2,500 μ long, 15 μ in diameter, aseptate.

Parenchyma fairly abundant, diffuse or in very short uniseriate lines of 3–5 cells, parenchyma cells 30–35 μ in diameter, pits simple, oval to round, 4–10 per cell.

Rays 10–15 per mm., 1–3 cells or 12–40 μ wide, 10–60 cells or 250–1,500 μ high, markedly heterogeneous with 2–8 marginal rows of vertical cells.

Holotype No. 5078 of the Museum of Birbal Sahni Institute of Palæobotany.

Bridelioxylon nov. gen.

Bridelioxylon cuddalorense nov. sp.

The species is represented by two specimens. The figured one measures 6 cm. in length and 10 cm. in diameter. It is an almost complete longitudinal half of the original stem and shows a part of the pith also (Pl. XVI, Fig. 8). The pith, however, does not show good preservation, it is formed of loosely packed parenchyma cells, filled here and there with some dark contents.

The preservation of the secondary xylem is very good. The finely polished transverse surface of the fossil shows growth marks quite distinctly to the naked eye (Pl. XVI, Fig. 8), under the microscope the contrast between the spring wood and late wood is marked. The spring

wood is much more developed than the late wood which forms only a narrow zone (Pl. XVI, Fig. 9). The vessels are medium-sized to small and just visible to the naked eye. Their distribution is primarily diffuse and exhibit no marked variation in size within the growth ring. The vessels are mostly in radial groups of 2–5. Both pore chains and pore multiples are commonly observed. Solitary vessels also occur commonly. The vessels in a group are generally unequal in size, and are mostly flattened at the places of contact. They are thick-walled and very commonly filled with a dark-coloured deposit. Tyloses are not seen. The vessel-segments are rather short, truncate or abruptly or attenuately tailed on one or both ends (Text-Fig. 13). The perforations are exclusively simple, and horizontal. Intervessel pitting is abundant. The pits are moderately large, alternate and distinctly vestured (Pl. XVI, Figs. 11, 12); the pit membrane, as seen in surface view, presents a punctate or dotted appearance. The intervessel pits are as a rule contiguous and so become hexagonal in outline. The vessel-ray pitting is simple; the pits are small to medium, rounded and many per cell (Text-Fig. 14). The vessel-parenchyma pits are not observed.

The fibres constitute the best preserved tissue of the wood and show all the details excellently. They are very thick-walled, and medium in length, They are laterally stretched and with very narrow lumina in the late wood, while in the spring wood they are equidiametric and more open. The fibres are always arranged in uniform radial seriations. They are usually empty, but sometimes filled with black deposit. They are libriform and typically septate. The septa are considerably thick. Pits to the fibres are small, simple and rounded to elliptical and placed linearly (Text-Fig. 15).

The parenchyma is not visible either to the naked eye or under a hand-lens. It is, however, present in limited amount. The parenchyma is mostly paratracheal and in 1–2 layered vasicentric sheaths (Text-Fig. 12; Pl. XVI, Figs. 9, 10). Single parenchyma cells (apotracheal type) are also met with scattered among the fibres. The cells of the parenchyma contiguous to the vessels are as a rule flattened to confirm to the vessel wall, while the rest are round to oval. They are thin-walled, and mostly filled with a dark-coloured deposit. Pits to the parenchyma cells are not observed.

The outlines of the xylem rays are visible to the naked eye, both on the transverse as well as longitudinal surfaces of the fossil. They are more or less fusiform or spindle-shaped and closely packed, forming a conspicuous feature in the tangential sections. The rays are 1–4 cells wide and 12–35 cells in height. The majority of them are triseriate, but uniseriate rays are not infrequent. The rays are heterogeneous and contain 1–2 marginal rows of vertical cells (Text-Fig. 15, Pl. XVI, Fig. 13). As compared with *Putranjivoxylon puratanam*, the rays here are not so markedly heterogeneous. The marginal vertical cells are quite conspicuous in both tangential and radial sections (Pl. XVI, Fig. 14). In tangential sections they form the pointed ends of the rays; the procumbent cells which fill the rest of the ray are polygonal

TEXT-FIGS. 12–15. *Bridelioxylon cuddalorense* nov. gen., nov. sp. Fig. 12. Semi-diagrammatic cross-section showing the distribution of the parenchyma (stippled) and the vessels, ×70. Fig. 13. A vessel-segment showing the tailed ends, and simple perforations, ×210. Fig. 14. Radial section showing the vessel-ray pitting, ×300. Fig. 15. Tangential section showing the general nature of the xylem rays, parenchyma and pitting on the fibres, ×150.

or rounded in outline. End-to-end ray fusions are of frequent occurrence. The ray cells are thick-walled, and filled with a dark content. The tangential walls of the rays show a few, simple, oval pits.

Comparison with the living species.—The important features of the fossil wood under investigation, that are of some diagnostic value, are the occurrence of vestured pitting, scanty paratracheal parenchyma and the details of the xylem rays. The evidence to date is to the effect that vestured pits are extremely consistent in their distribution, and for this reason their presence or absence appears to be of decided diagnostic importance in the identification of angiosperm woods. According to Bailey (1924) nearly 25 families are characterised by the possession of vestured pits, the important ones of which are Combretaceæ, Euphorbiaceæ (only two genera), Leguminosæ, Melastomaceæ, Myrtaceæ, Lythraceæ, Sonneratiaceæ, Vochysiaceæ, etc. When significant details of all the tissues of the wood are taken into consideration along with the nature of intervessel pitting it is found that the South Indian fossil specimen belongs to the family Euphorbiaceæ. Among Euphorbiaceæ it is particularly with the wood of *Glochidion* type that a strong resemblance is indicated. The wood of *Glochidion* type as has been mentioned previously shows simple perforations, broad heterogeneous rays, typically septate fibres; the xylem here is either absent or occurs sparingly. From a comparison with the genera like *Phyllanthus*, *Antidesma*, *Glochidion*, *Bridelia* and *Cleistanthus* it is seen that the fossil is nearer to the last two genera.

Both *Bridelia* and *Cleistanthus* resemble our fossil in the nature and arrangement of the vessels (especially in the vestured nature of the intervessel pitting), the fibres and the parenchyma. *Cleistanthus*, however, differs from the fossil in its minute intervessel pits and much longer rays which are not fusiform. The uniseriate rays in this genus are more numerous when compared to the fossil wood; *Bridelia*, on the other hand, agrees with the fossil very closely in all its characters.

Comparison with the fossil species.—The present specimen differs markedly from *Putranjioxylon puratanam*, in possessing exclusively simple perforations, vestured intervessel pits, very limited, vasicentric parenchyma, and relatively short, more or less spindle-shaped xylem rays which are much less heterogeneous.

Among fossil woods of Euphorbiaceæ described from outside India the only comparable ones are *Euphorbioxylon speciosum* (Felix, 1887), and *Phyllanthinium Pseudo-hobashiraishi* (Ogura, 1933; Watari, 1943).

Euphorbioxylon speciosum from Columbia is similar to our fossil in possessing limited amount of parenchyma in the form of vasicentric sheaths, and in its rays which are 1–3 seriate and heterogeneous with 1–2 marginal rows of vertical cells. But the Columbian species differs markedly in not possessing growth rings, in its generally solitary vessels, the absence of vestured intervessel pits, and lastly in the aseptate nature of its fibres.

Phyllanthinium pseudo-hobashiraishi from Japan is considerably similar to our specimen in the size, shape and distribution of the vessels, in the nature of the parenchyma and the xylem rays. But it differs in not possessing vestured pits; moreover the vessels in the Japanese species are profusely tylosed, fibres are long and fusiform, parenchyma is crystalliferous and the growth rings are faint.

For detailed comparisons reference may be made to the table at the end.

Name of the fossil and diagnosis.—Owing to its marked resemblance with the modern genus *Bridelia* of the family Euphorbiaceæ a new generic name *Bridelioxylon* has been proposed to the present fossil. It is specifically named as *Bridelioxylon cuddalorense* after the Cuddalore series.

Among the modern flora of India species of *Bridelia* are widely distributed throughout India, being found in Punjab, Uttar Pradesh, Bihar, Orissa, Central India and South India (Gamble, 1922; Pearson and Brown, 1932).

Bridelioxylon nov. gen.

A diffuse porous wood.

Growth rings distinct.

Vessels small to medium, fairly visible to the naked eye as dots; solitary or in numerous radial groups of 2–5 or more vessels; thick-walled, circular or flattened; tyloses not seen; vessels, commonly filled with a dark deposit; vessel-segments, medium, truncate or abruptly or attenuately tailed on one or both ends; perforations simple, horizontal; intervessel pits moderately large, alternate, vestured and usually hexagonal; vessel-ray pits small to medium, simple, rounded, many per cell.

Fibres libriform, medium in length, arranged regularly in radial seriations; late wood fibres very thick-walled, laterally stretched, with narrow lumina, spring wood fibres equidiametric with wide lumina; septate, septa thick. Pits simple, small and rounded, placed linearly.

Parenchyma limited, not visible to the naked eye; mostly paratracheal in 1–2 layered vasicentric sheaths; often also diffuse; cells round to oval, commonly filled with dark contents.

Rays' outlines fairly visible to the naked eye; numerous, closely packed, evenly distributed; 1–4 seriate 12–35 cells high, fusiform or spindle-shaped; heterogeneous, but not markedly so, there being only 1–2 marginal rows of vertical cells; end-to-end ray fusions frequent; cells thick-walled, commonly filled with a dark deposit; pits on tangential walls simple and oval.

Bridelioxylon cuddalorense nov. sp.

Vessels 90–140 μ in diam.; evenly distributed. 20 per sq. mm., solitary or in groups of 2–5, thick-walled, perforations simple, horizontal; vessel-segments 175–600 μ, truncate or tailed abruptly or alternately.

Fibres 1400–1550 μ long, 12 μ in diam. Libriform, walls of late wood fibres 8–10 μ thick, of spring wood fibres 2-5 μ thick; septate, septa thick; pits simple, small, rounded.

Parenchyma limited, in 1–2-layered vasicentric sheaths, often also diffuse. Cells 18–25 μ in diam.

Rays 7–12 per mm. 1–4 cells or 10–70 μ wide, majority 3 seriate, 12–35 cells or 340–500 μ high, majority 12–19 cells high. Heterogeneous with 1–2 marginal rows of vertical cells.

Holotype No. 5028 of the Museum of Birbal Sahni Institute of Palæobotany.

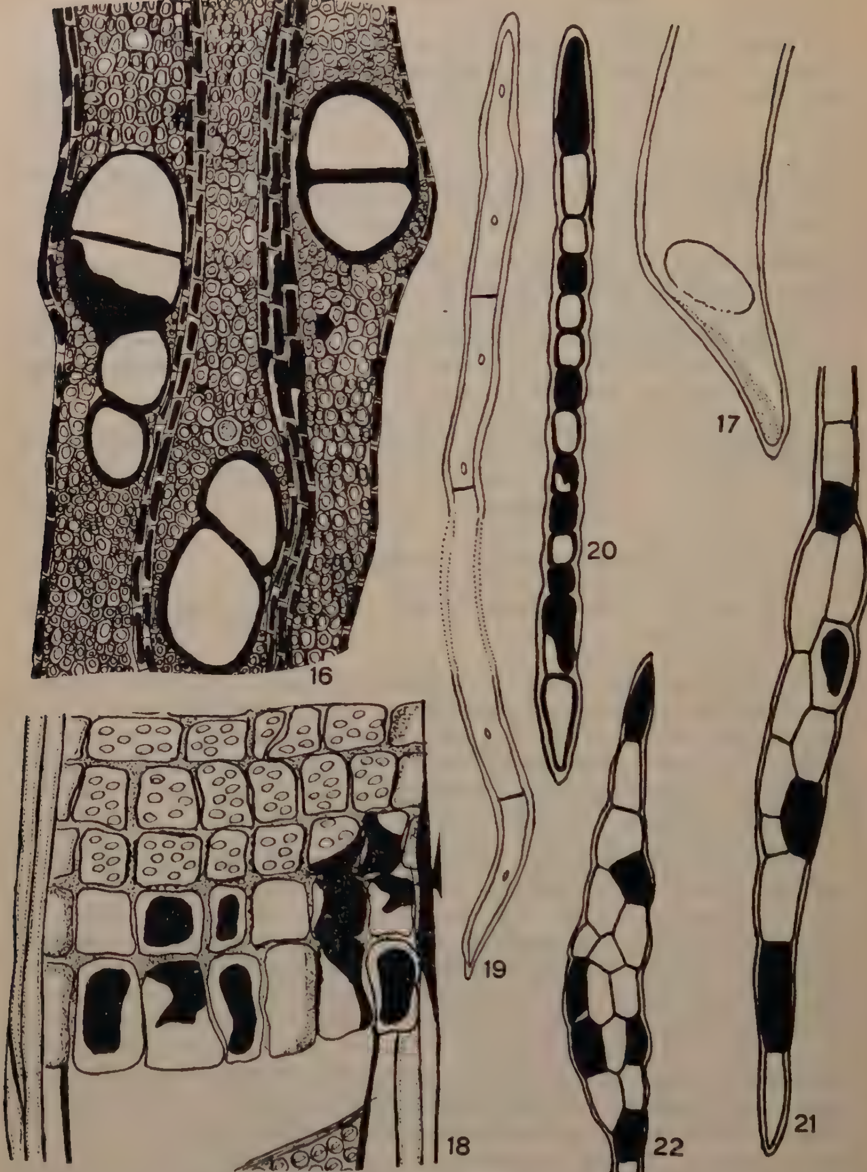
Glochidioxylon nov. gen.

Glochidioxylon tertiarum nov. sp.

The species is represented by two small, highly silicified, decorticated stem pieces.

The central part of the stem shows the pith. The pith is angular and made up of rounded parenchyma cells, often filled with a dark-coloured deposit (Pl. XVII, Fig. 15). The primary xylem is clearly preserved; it shows numerous, minute vessels arranged radially. The pitting of the primary xylem elements is either of annular or reticulate type. The phloem tissue, however, is not preserved.

The fossil exhibits faint growth rings to the naked eye but under the microscope no distinction can be made out between the spring wood and the late wood. The vessels are very indistinctly visible to the naked eye. They are small to medium and arranged in numerous radial multiples of 2–4, or sometimes more (Pl. XVII, Fig. 17). The distribution of the vessels is primarily diffuse. The vessels are oval or rounded when solitary, when in radial multiples they are usually flattened at the places of contact showing a chain formation and constricted in the fused portion, but sometimes the vessels in the radial groups do not show any flattening and then are oval or elliptical in cross-sections. They are thick-walled, and are either empty or filled up with some solid dark deposit. Tylosic ingrowths are not observed. The vessel-segments are of medium size, truncate or attenuately tailed on one or both the ends (Text-Fig. 17). The perforations are exclusively simple, and horizontal or sometimes steeply inclined. Intervessel pitting is very conspicuous. The pits are fairly large, distinctly bordered, alternate and circular, the orifice of the pits is more or less lenticular or slit-like and orientated horizontally or often obliquely (Pl. XVII, Fig. 18). The



Text-Figs. 16–22. *Glochidioxylon tertiarum* nov. gen., nov. sp. Fig. 16. Cross-section showing the distribution of the fibres, parenchyma (slightly bigger cells) and the vessels, ×210. Fig. 17. A part of the vessel-segment showing the tailed nature and simple perforation, ×210. Fig. 18. Radial section showing the vessel-ray pitting, × 300. Fig. 19. A libriform fibre showing the pitting, × 300. Fig. 20. Uniseriate ray with marginal vertical cells, ×210. Figs. 21–22. Multiseriate rays with marginal vertical cells, ×210.

vessel-ray pits are abundantly preserved; they are simple to very narrowly bordered, of medium size, oval to rounded or tangentially elongated and 2–8 per cell, distributed irregularly (Text-Fig. 18).

The fibres constitute the fundamental element of the wood in cross-section since the parenchyma is very meagrely represented. They are libriform and invariably aligned in regular, undisturbed radial seriations. They are rounded or polygonal when seen in transverse sections (Text-Fig. 16), and are considerably thick-walled. The fibres are long and septate; the septa in most cases are fairly thick. The interfibre pits are simple, rounded or longitudinally stretched; they are only a few per each fibre and rather widely spaced in a linear manner. The fibre pitting is seen distinctly both in the tangential and radial sections (Text-Fig. 19).

The wood parenchyma is very scanty; only a few scattered cells are observable here and there among the fibres (Text-Fig. 16). As the form and often the size of these scattered parenchyma cells is nearly the same as the fibres, to distinguish the former from the latter in cross-sections presents a rather difficult task. In longitudinal sections, however, the parenchyma is always clearly distinguishable by its horizontal walls. The parenchyma cells are rounded or polygonal in transverse sections; pitting to these cells is not seen.

The outlines of the xylem rays are fairly visible to the naked eye both on transverse as well as longitudinal surfaces of the fossil. They represent the most conspicuous of the tissues in the tangential sections. The rays are uniformly and closely distributed and numerous. They are 1–4 seriate (Pl. XVII, Figs. 19, 20). They are distinguishable into two types, the uniseriates and multiseriates. The uniseriate rays are comparatively fewer while the multiseriate ones are the most abundant. The rays in general are of considerable heights; in most cases they are 20–75 cells high. Here and there rays as high as 105 cells are also met with. The rays, as a rule, are always markedly heterogeneous and exhibit a good variety in the proportion and arrangement of the vertical cells to the procumbent cells. The uniseriate rays are made up either entirely of vertical cells (Text-Fig. 20), or procumbent cells, or have vertical cells at the margins and procumbent cells in the middle; the last type is rather sporadic. The multiseriate rays have marginal rows (1–6) of vertical cells at each end and procumbent cells of various sizes and forms in the middle (Text-Figs. 21, 22; Pl. XVII, Figs. 19, 20); or as is seen in some rare cases the margins may possess both vertical and procumbent cells intermingled with each other. The ray cells are thick-walled and plugged with a dark coloured deposit. Pits to the tangential walls of these cells are often observable, but their structural details are not clear.

The fossil shows some knots in the tangential sections. Each knot consists of more than one branch base. In one case as many as six branch bases can be seen clubbed together. The pith of the branch base is more or less angular and purely parenchymatous; the cells are mostly filled up with a dark substance. The primary xylem is very

compact, consisting of numerous, very small vessels arranged uniformly in radial chains (Pl. XVII, Fig. 17). The pith is circumscribed by a parenchymatous tissue in which the majority of the cells contain the same dark substance. The whole branch base, in turn, is encircled by the xylem rays of the parent stem, cut at various angles and different levels presenting a rather characteristic look in the tangential sections.

Comparison with the living species.—The fossil wood under investigation is characterized by the following characters: vessels small to medium, in numerous radial multiples of 2–4. Intervessel pits large, circular, distinctly bordered and alternate. Perforations simple, horizontal or sometimes steeply inclined. Fibres libriform, septate, long, with few simple pits placed in a linear manner. Parenchyma very scanty, being represented by a few irregularly scattered cells. Rays 1-4 cells wide, of two types, markedly heterogeneous and of considerable heights. Among the structural features of this fossil there is none which if considered alone is striking enough to help in its identification. The only method of determining its affinities is the laborious one of searching for similar combinations of anatomical characters in extant dicotyledons. This combination of characters is met with in varying extents in the members of the families like Bixaceæ, Celastraceæ, Connaraceæ, Pittosporaceæ, Flacourtiaceæ, Lauraceæ, Burseraceæ and Euphorbiaceæ, especially the last five families, with which the fossil has been compared in detail.

The woods of Pittosporaceæ agree with the fossil to a considerable extent in some features, but the xylem rays in this family are entirely homogeneous as against the markedly heterogeneous rays of our fossil. In Flacourtiaceæ genera like *Doyalis* and *Taraktogens* approach our fossil in general features, but they differ strongly in possessing scalariform perforations and much broader rays (Gilg, 1908; Metcalfe and Chalk, 1950).

In Lauraceæ genera like *Phœbe*, *Litsea*, *Tetradenia* (Dadswell and Eckersley, 1940) present to a considerable extent many similarities to our fossil, but all of them differ fundamentally in possessing fairly abundant xylem parenchyma.

In Burseraceæ genera like *Garuga* and *Bursera* agree with our fossil to a great extent in general features of the anatomy, but differ in possessing horizontal gum ducts, non-libriform fibres; the parenchyma in these genera although scanty, is represented by paratracheal type in contradistinction to the diffuse type present in the fossil wood (Pearson and Brown, 1932).

In the family Euphorbiaceæ it is with the wood type of the *Glochidion* group of the Phyllanthoideæ section that the fossil wood from South India resembles to a great extent. The *Glochidion* group as has already been mentioned is characterized by simple perforations, typically septate, libriform fibres, markedly heterogeneous rays, and very scanty parenchyma. *Glochidion*, *Bischofia*, *Antidesma* (Foxworthy, 1907; Kanehira, 1924 *a*, 1924 *b*, 1926; Pearson and Brown, 1932), seem

to be very similar to our fossil, particularly the former two genera; but none of them are quite the same as the fossil in each and every respect. Consequently it has not been possible for hazarding the statement that the fossil from South India resembles any one of these aforementioned genera exclusively. It can be said that the present fossil is an Euphorbiaceous wood resembling the wood type of *Glochidion* group, excluding the genera *Bridelia* and *Cleistanthus* which possess vestured intervessel pits, of the Phyllanthoideæ section.

Comparison with the fossil species.—The genera *Putranjivoxylon* and *Bridelioxylon* described from the same locality differ markedly from the present specimen.

Thus, *Putranjivoxylon puratanam* differs from the fossil under study in possessing often scalariform perforations and a fairly abundant apotracheal parenchyma; the nature of the rays in this genus is also quite different from that of the present specimen.

Bridelioxylon cuddalorense differs from the present wood in possessing distinctly vestured intervessel pits, 1–2 cells thick vasicentric parenchyma and relatively short fusiform or spindle-shaped xylem rays.

Paraphyllanthoxylon arizonense (Bailey, 1924), described from the Cretaceous of Arizona, shows several common features with our fossil, but possesses much broader rays and abundantly tylosed vessels.

Phyllanthinium pseudo-hobashiraishi (Ogura, 1933; Watari, 1943), described from the Tertiary of Japan while resembling our fossil in several characters, differs from it in possessing very abundantly tylosed vessels, much shorter and weakly heterogeneous rays, and the presence of crystalliferous elements in the parenchyma.

For detailed comparisons with all the species of fossil Euphorbiaceous woods a reference may be made to the adjoining table.

Name of the fossil and diagnosis.—From the above description it can be gathered that the fossil under investigation belongs to the family Euphorbiaceæ, showing its resemblances in particular with the wood type of the *Glochidion* group of the section Phyllanthoideæ. Bailey (1924) describing a fossil wood from the Cretaceous of Arizona, which according to him shows resemblances with *Phyllanthus* and other structurally similar representatives of Phyllanthoideæ, instituted a new name *Paraphyllanthoxylon* for the fossil woods showing apparent similarities to the section Phyllanthoideæ. Ogura (1933) created a new generic name *Phyllanthinium* for his fossil wood resembling according to him, genera like *Antidesma*, *Glochidion*, *Bischofia* and *Bridelia*. Our fossil too, it is obvious, resembles these general which by virtue of their anatomical characters fall under the wood type of *Glochidion* group. Since the section Phyllanthoideæ could be split up into two groups, *Glochidion* and *Aporosa* based on the wood anatomy, each group characterized by its own set of anatomical characters, it might be better, and probably more natural, if the fossil woods showing affinities to these groups be named after these groups, unless they exhibit unmistakable resemblances with some particular genus, instead of grouping

such woods under a single rather broad genus *Phyllanthinium* or *Paraphyllanthoxylon*. The name *Paraphyllanthoxylon* may, however, be retained for the woods coming from the Cretaceous horizon.

Thus the new generic name *Glochidioxylon* that has been proposed for the fossil, does not indicate in particular the resemblances of the fossil with the extant genus *Glochidion*, but indicates, on the other hand, strong similarities to the wood type of the *Glochidion* group of the Phyllanthoideæ section. The fossil is specifically named as *Glochidioxylon tertiarum*.

Glochidioxylon nov. gen.

A diffuse porous wood.

Growth rings faint to the naked eye, but disappear under the microscope.

Vessels small to medium, indistinct to the naked eye; arranged in numerous radial multiples of 2–4 or more, occasionally also solitary; thick-walled, oval or rounded when solitary and usually flattened when in radial groups; tyloses not observed; vessel-segments medium, truncate or attenuately tailed on one or both sides; perforations simple, horizontal or sometimes steeply inclined; intervessel pits fairly large, distinctly bordered, circular and alternate orifice lenticular or slit-like, placed horizontally or obliquely; vessel-ray pits of medium size, simple or narrowly bordered, oval to rounded, often tangentially stretched and 2–8 per cell.

Fibres medium to long; libriform; arranged uniformly in undisturbed radial seriations; rounded or polygonal in cross-sections; septate, septa thick; pits to the fibres few, simple, rounded or slightly elongated longitudinally, arranged in a linear manner.

Parenchyma very scanty, consists of a few irregularly scattered cells among the fibres. Cells rounded or polygonal.

Rays numerous, evenly distributed; outlines fairly visible to the naked eye; 1–4 seriate, 20–75 cells high, often as high as 105 cells; markedly heterogeneous with 1–6 marginal rows of vertical cells; rays exhibit considerable variety in the proportion and distribution of vertical cells to the procumbent cells; cells commonly filled up with a dark deposit.

Glochidioxylon tertiarum nov. sp.

Growth rings not distinct under the microscope.

Vessels 75–130 μ in diam., evenly distributed, 20–25 per sq. mm.; mostly in radial multiples of 2–4, thick-walled; tyloses not observed; vessel-segments 500–750 μ, truncate or attenuately tailed; intervessel pits alternate, distinctly bordered, circular; orifice lenticular or slit-like placed horizontally or obliquely.

Fibres libriform, 1600–2500 μ in length, 15–22 μ in diam., septate, septa of considerable thickness.

Parenchyma very scanty, diffuse; cells 15–25 μ in diam.

Rays 5–12 per mm.; 1–4 cells broad, majority 2–3 seriate or 25–40 μ broad, 20–75 cells or 550–2200 μ high, ray cells commonly filled up with a dark substance.

Holotype: No. 5030 of the Museum of Birbal Sahni Institute of Palæobotany.

ACKNOWLEDGEMENTS

The author is extremely grateful to Dr. R. V. Sitholey under whose kind guidance and constant encouragement the work has been carried out. He also wishes to express gratefulness to Dr. K. A. Chowdhury of Forest Research Institute, Dehra Dun, for making available to him several specimens of living woody genera for purposes of comparison. The paper forms a part of the thesis accepted by Lucknow University for the Degree of Doctor of Philosophy.

SUMMARY

Three new genera of the fossil woods of Euphorbiaceæ have been described in detail for the first time from Indian horizons. They are named as *Putranjivoxylon puratanam*, *Bridelioxylon cuddalorense* and *Glochidioxylon tertiarum*, by virtue of their striking resemblances to the modern genera *Putranjiva*, *Bridelia* and the wood-type of the *Glochidion* group of the Phyllanthoideæ section. All these woods have been collected from the Tertiary rocks of Mortandra in South Arcot District, 5 miles North-West of Pondicherry.

Table showing the salient features

Species	Growth rings	Vessels	Intervessel pitting
Euphorbioxylon speciosum Felix, 1887	..	Diffuse, mostly solitary, oval to rounded, perforations simple	Pits large, rounded or hexagonal bordered
Paraphyllanthoxylon arizonense Bailey, 1924	Feebly differentiated	Large, diffuse, 8–14 per sq. mm., solitary or in radial groups of 2–4, tyloses abundant, perforations simple	Pits crowded, hexagonal
Dryoxylon drypeteoides Bancroft, 1932	Very fine to the naked eye, but disappear under the microscope	Small, diffuse, solitary or in radial rows of 3 or more, other details not clear	Pits small forming a close network, details not preserved
Phyllanthinium pseudohobashiraishi Ogura, 1933, Watari, 1943	Present, but not prominent	Medium, diffuse, solitary or in radial groups of 2–4, tyloses abundant, perforations simple	Abundant, bordered, oval or angular
Euphorbioxylon Lefrancii Boreau, 1951	Very faint	Medium, diffuse, 6 per sq. mm., mostly solitary, sometimes in radial groups of 2, vessel-segments tailed, perforations simple	..
Haveoxylon microporosum Kruse, 1954	Very indistinct, possibly absent	Medium, extremely variable in size, diffuse, 30–100 per sq. mm. Solitary and in radial multiples of 2–9, tyloses abundant, perforations simple	Alternate, fine, details not preserved
Putranjivoxylon puratanum Ramanujam	Absent	Small to sometimes medium, diffuse, 25 per sq. mm. mostly in radial multiples of 2–5 solitary vessels few, tyloses absent, vessel-segments short, truncate or abruptly or attenuately tailed, perforations simple or often scalariform	Abundant, pits small, alternate, bordered, circular with oval to elliptical apertures
Bridelioxylon cuddalorense Ramanujam	Distinct	Small to medium, diffuse, 20 per sq. mm., solitary or in radial groups of 2–5, tyloses absent, commonly filled with a dark deposit, vessel-segments medium, truncate or abruptly or attenuately tailed, perforations simple	Pits moderately large, alternate, distinctly vestured, usually hexagonal
Glochidioxylon tertiarum Ramanujam	Faint to the naked eye, but disappear under the microscope	Small to medium, diffuse, mostly in radial multiples of 2–4, 20–25 per sq. mm., tyloses absent, vessel-segments medium, truncate or attenuately tailed, perforations simple	Pits fairly large, distinctly bordered, alternate, circular, orifice lenticular, placed horizontally or obliquely

of fossil woods of Euphorbiaceæ

Fibres	Parenchyma	Rays	Locality and age
Libriform	Scanty, paratracheal	1–5 seriate, heterogeneous	Columbia, Tertiary
Thick-walled, septate, pits slit-like, simple or very narrowly bordered	Paratracheal, scanty, thin-walled, large-celled	1–7 seriate, 3–80 cells high, markedly heterogeneous	Arizona, Cretaceous
Thick-walled, details not preserved	Apotracheal in numerous closely set uniseriate tangential lines of varying regularity	1–4 seriate, slightly heterogeneous	East Africa, Miocene (?)
Libriform, septate, or aseptate, variable in size, irregular in arrangement, pits small, simple (?)	Very scanty, vasicentric, crystalliferous	1–4 cells wide, fusiform, slightly heterogeneous, 13–38 cells high, rays often fuse vertically end to end	Japan, Tertiary
Libriform, disposed in radial rows aseptate (?), pits simple	Very scanty, paratracheal	Uniseriate, heterogeneous, 9–20 cells high, ray cells filled with a black deposit	Algeria, Tertiary
Thick-walled, length not determined, aseptate (?)	Fairly abundant, paratracheal and apotracheal, the former scanty, the latter represented by multiseriate tangential bands	1–2 seriate, strikingly heterogeneous with alternation from 1-celled to 2-celled condition, 10–40 cells high.	Wyoming, Eocene
Libriform long, arranged regularly in radial seriations, aseptate, pits very small, simple, oval	Fairly abundant, apotracheal (1) in the form of numerous closely scattered cells or (2) as very short uniseriate lines, pits simple, round to ovall 4-10 per cell	Evenly distributed. 1–3 seriate, 10 60 cells high, markedly heterogeneous, short multiseriate parts with procumbent cells alternating with portions formed of vertical cells in a single row, ray cells crystalline	South India, Tertiary
Libriform, medium arranged regularly in radial rows, septate, septa thick, pits simple, small, and rounded	Limited, mostly paratracheal, in 1–2 layered vasicentric sheaths, often also diffuse	Evenly distributed, 1–4 seriate, 12–35 cells high, heterogeneous with 1–2 marginal rows of vertical cells	South India, Tertiary
Libriform, medium to long, arranged in regular radial chains, septate, septa thick, pits simple, few rounded, arranged in a linear manner	Very scanty, as irregularly scattered cells among the fibres	Uniformly distributed, 1–4 seriate, 20–75 cells high, markedly heterogeneous with 1–6 marginal rows of vertical cells	South India, Tertiary

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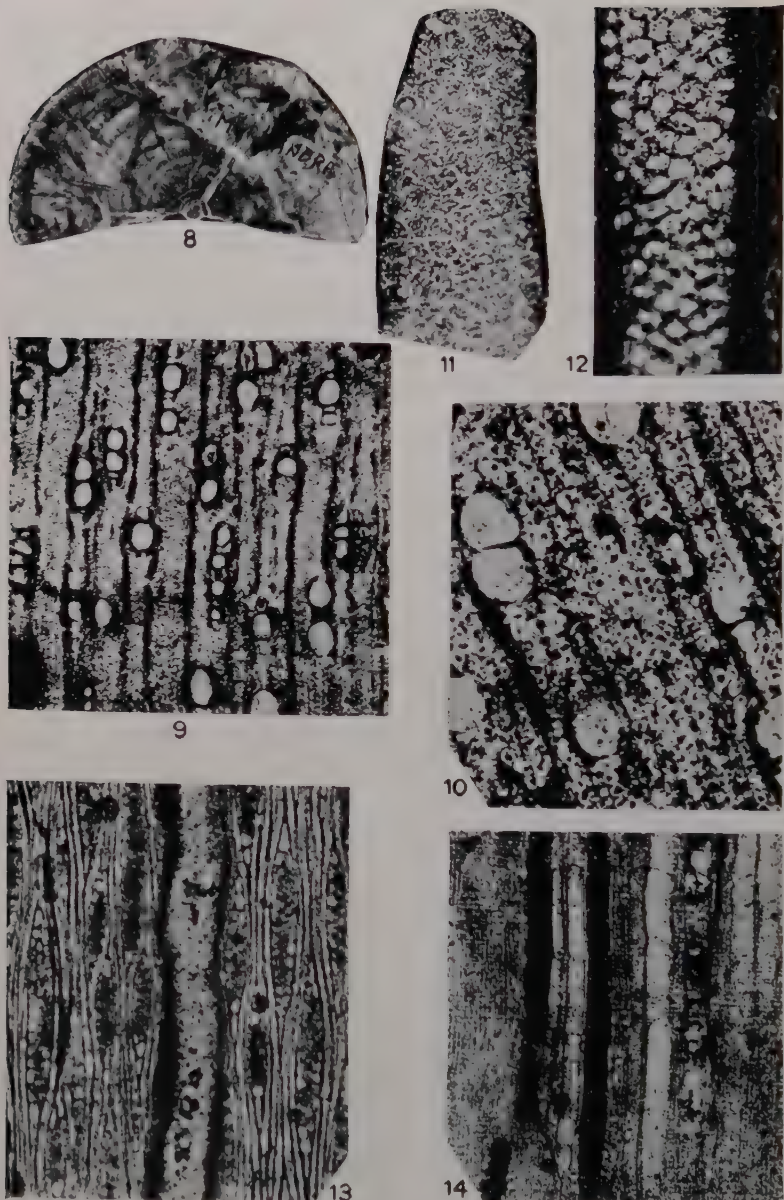

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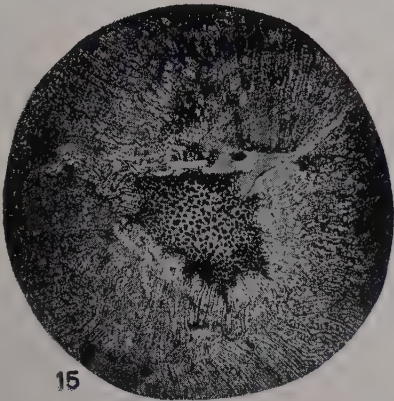

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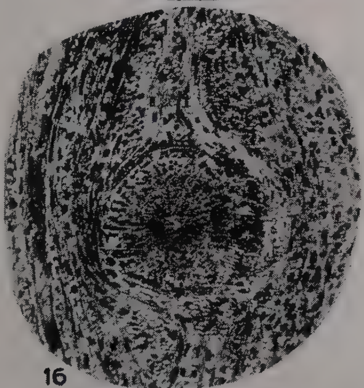

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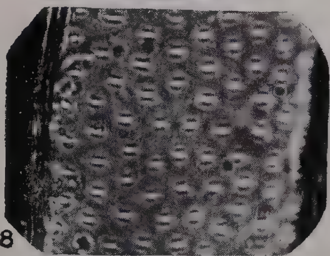

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EXPLANATION OF THE PLATES

PLATE XV

FIGS. 1–7. *Putranjivoxylon puratanam* nov. gen., nov. sp.

FIG. 1. Cross-section showing the distribution of the parenchyma and the vessels, ×95.

FIG. 2. Cross-section showing the radial multiples of vessels, and the diffuse parencyhma cells, ×95.

FIG. 3. Vertical scalariform perforation plate, ×150.

FIG. 4. Oblique scalariform perforation plate, ×150.

FIG. 5. Tangenital section showing the uniseriate and multiseriate xylem rays. Note the crystals in the ray cells, ×95.

FIG. 6. Tangential section showing the multiseriate rays, ×95.

FIG. 7. Radial section showing the crystals in the ray cells, ×150.

PLATE XVI

FIGS. 8–14. *Bridelioxylon cuddalorense* nov. gen., nov. sp.

FIG. 8. Polished transverse surface of the fossil showing the growth rings, and the general structure, ×½ nat. size.

FIG. 9. Cross-section showing the late wood and spring wood fibres and the radial groups of vessels. Note the dark thin sheath of vasicentric parenchyma around the vessels, × 35.

FIG. 10. Cross-section slightly enlarged to show the vasicentric parenchyma and the nature and distribution of the fibres, ×95.

FIGS. 11, 12. Intervessel pitting to show the vestured nature of the pits, ×500.

FIG. 13. Tangential section showing the xylem rays and the septate fibres, ×95.

FIG. 14. Radial section, ×35.

PLATE XVII

FIGS. 15–20. *Glochidioxylon tertiarum* nov. gen., nov. sp.

FIG. 15. Central part of the wood to show the angular pith and the primary xylem, ×95.

FIG. 16. Tangential section showing a branch base, ×95.

FIG. 17. Cross-section showing the radial chains of vessels and the general nature and distribution of the fibres, ×95.

FIG. 18. Intervessel pits, ×500.

FIG. 19. Tangential section showing the multiseriate heterogeneous rays, ×95.

FIG. 20. Tangential section showing both the types of rays, the uniseriates entirely with vertical cells and the multiseriates with marginal vertical cells, ×95.

ON THE RECENT INTRODUCTIONS IN THE FLORA OF PURNEA (BIHAR)

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A floristic survey of the Purnea District by the author spread over a period of about 7 years (1948–55) and in various seasons of the year, yielded the list of plants given in Appendix I. In all 644 species are noted, of which more than half are not mentioned in Haines' Botany (1921–25) from Purnea (Appendix II) though Haines had made a thorough personal study of the flora of the district in the late twenties of the present century. It is interesting to note that within the short period of about 30 years, since the publication of Haines' book, over 300 plants have been introduced in the district, 274 of them reported from districts of Bihar other than Purnea, and 36 new to the State.

The present paper is an attempt to study the causes that made introductions of plants from other states possible, the agencies that brought these about, and the sources from which these plants could have come.

An Analysis of the New Introductions

Leaving aside the plants found near human habitations (where the list is not complete and where all introductions have possibly been by the agency of man), the proportion of the newly introduced plants to the total is as under.

Zone	Total No. of plants in the zone	Number of new introductions	Percentage of new over total
Aquatic and Amphibious	124	16	12·9
Low Grass-lands ..	124	9	7·24
High Grass-lands ..	122	2	1·6
Scrub Jungles ..	94	1	1·06
Monsoon Forests ..	165	5	3·0

The highest percentage of introductions are in the Aquatic and Amphibious zone and in the Low Grass-lands, slightly lower in the Monsoon Forests and very low in the Scrub Jungles and in the High Grass-lands.

Appendix I also shows that almost all the new introductions are herbs, shrubs and trees being rare.

Adaptations for Dispersal

Adaptations among the newly introduced plants for dispersal and the agencies by which they could be transported were studied (based mainly on Ridley, 1930).

1. Seed, fruit, or whole plant edible: dispersed mainly by birds:

Myriophyllum indicum Willd., *Ceratophyllum demersum* Linn., *Alisma reniforme* Don., *Lagarosiphon alternifolia* (Roxb.) Druce, *Spirodela polyrrhiza* (Linn.) Schleid., *Cyperus polystachyos* Rottb., *Brachiaria setigera* (Retz.) Hubbard, *Pseudoraphis aspera* (Koen.) Pilger, *Heliotropium subulatum* Hochst., *Plectronia parviflora* Bedd., *Vitis lanata* Roxb., *Solanum pubescens* Willd., *Eriocaulon intermedium* Koern., *Lolium perenne* Linn.

2. Seed, fruit, whole plant, or bits buoyant; dispersed mainly by adhering to the body of aquatic birds:

Myriophyllum indicum Willd., *Ceratophyllum demersum* Linn., *Alisma reniforme* Don., *Aponogeton crispum* Thunb., *Lagarosiphon alternifolia* (Roxb.) Druce, *Spirodela polyrrhiza* (Linn.) Schleid., *Cyperus polystachyos* Rottb., *Diplacrum caricinum* R. Br., *Eriocaulon intermedium* Koern., *Staurogyne glauca* O. Ktz., *Nesæa lanceolata* Koehne, *Ludwigia parviflora* Roxb., *Sphenoclea zeylanica* Gaertn., *Cyperus kyllinga* Endl., *Cyperus cephalotes* Vahl., *Alternanthera echinata* Sm., *Eichhornia crassipes* Solms., *Aegenetia pedunculata* (Roxb.) Wall., *Veronica anagallis* Linn.

3. Seed, fruit or whole plant buoyant; carried by rivers to long distances and drift with flood waters:

All plants of list 1 (except *Vitis lanata* Roxb., *Plectronia parviflora* Bedd. and *Solanum pubescens* Willd.).

All plants of list 2 and also *Neptunia oleracea* Lour., *Evolvulus nummularius* Linn., *Asystasia macrocarpa* Nees., *Aponogeton crispum* Thunb., *Peperomia pellucida* (Linn.) H. B. & K., *Pilea peploides* Hook. & Arn.

4. Fruit or seed light and feathery or winged; disperesd by winds and cyclones:

Urtica parviflora Roxb., *Pilea peploides* H. B. & K., *Lolium perenne* Linn., *Derris scandens* (Roxb.) Benth., *Dioscorea oppositifolia* Linn.

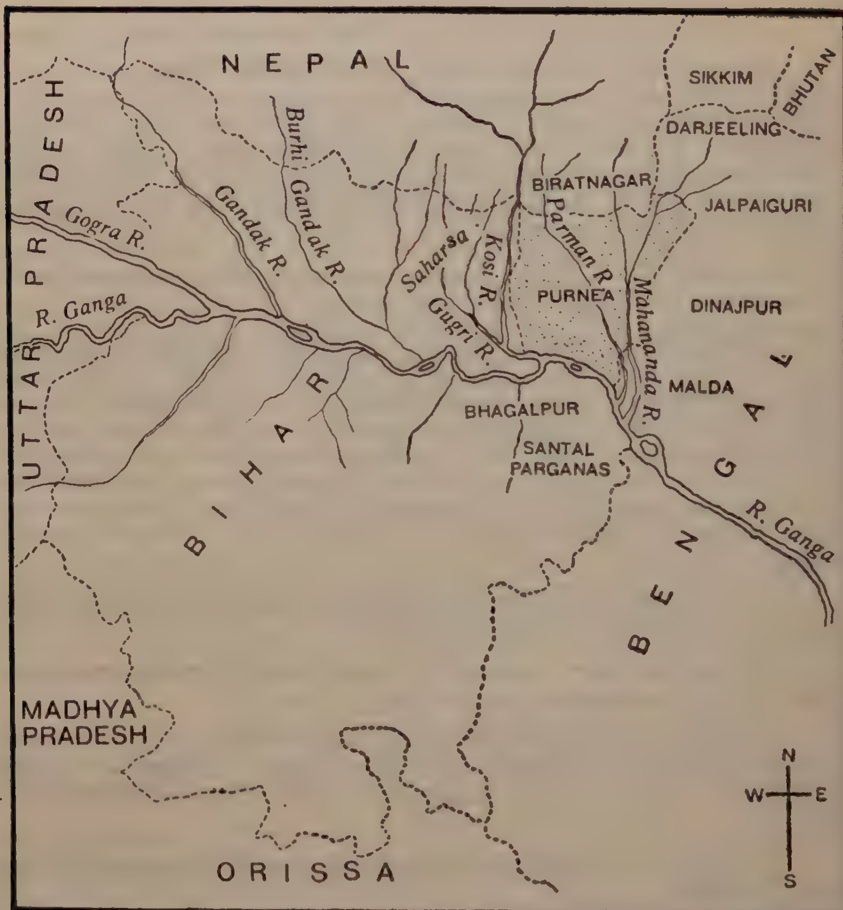
The physical features, rivers, climate, winds and birds of Purnea were studied to get an idea as to how the new introductions could have taken place.

Physical Features

(Based mainly on the *District Gazetteer*, 1911, and Srivastava, 1955 *a*)

The district (*see* map) lies in the extreme north-east of the province. It has on its north the Biratnagar District of Nepal and the Darjeeling

District of Bengal. On its east, it has the Jalpaiguri, Dinajpur and Malda Districts of Bengal. On its south it has the river Ganga which separates it from the Bhagalpur and Santal Pargana Districts. On its east lies the Saharsa District.



Purnea District and its Neighbourhood

Purnea District, like the rest of North Bihar, is a low plain (elevation 125 ft. above sea-level) lying between the Himalayas in the north and the high lime-stone built left bank of the Ganga on its south. The soil is a sandy alluvium.

The rivers are: Kosi in the west, Mahananda in the east and the Panar (Parman, Parwana) running a south-east course and dividing the district into two halves. The Kosi is formed by the confluence of 7 streams in the east of Nepal. The Mahananda arises below the

Mahaldiram Hills in the Darjeeling District and flowing southwards forms the boundary between Purnea and Jalpaiguri Districts for a distance of 8 miles. Its tributaries come from Jalpaiguri District, Dinajpur District and Nepal. The Panar and its tributaries come from lower Nepal and Nepal Terai. The Kosi has been the chief river of the district in the past. Due to excessive deforestation in its upper reaches and in those of its tributaries in Nepal, and the consequent loss of top vegetation, the Kosi comes in floods with extreme suddenness. Its tributary Arun is cutting gorges in the Himalayas, therefore the Kosi brings an unlimited amount of rocks, boulders, sand and coarse silt, all of which get deposited in the bed of the river as it flows through the plains of Bihar. This accumulation naturally elevates the bed of the river and forces it to change its course. This happens every few years. A new channel is formed and the old one is left behind. When the river changes course, vast areas of arable land get covered with a layer of sand. It is therefore that the north-west part of Purnea shows only old channels of Kosi and sand-covered uplands alternating with each other. The north-east part of Purnea also shows a sandy soil, perhaps the sand was deposited by the Kosi ages back.

Due to defective drainage in the southern part of the district, the Kosi, its old channels, and the other rivers and rivulets, every year overflow their banks and inundate the country for hundreds of miles. The swamps and marshes and all the low lands get filled up with water. As the water recedes from over the slightly elevated lands, it leaves behind it a layer of fine sand and coarse silt.

CLIMATE

(Based mainly on the *District Gazetteer*, 1911, the *Climatological Atlas*, 1943, the data received from the Director of Meteorological Observatories, Poona, and the author's own observations)

The climate is of the monsoon type with a dry cool winter from middle of October to middle of February, and a dry hot summer from middle of February to early June. In the hot wet season from about the 1st of June to middle of October, Purnea Town gets about 60 inches of rainfall, Kishangunj gets 79·6 inches and Kaliagunj gets about 82 inches. But the rainfall is irregular and uneven, it falls in torrents rather than in evenly spread showers, so that over most of the excessively grazed land and in the cultivated fields, it has no chance to be absorbed in the soil but rushes down carrying the precious top soil.

Winds blow in Purnea from every direction in one part of the year or the other. The surface winds blow from north-east in November-December, and from east in May–September; the westerly winds in February–April are very strong and dry and are blowing away the top soil especially in the tree-less plains of Araria. The upper winds move from south-east in July–September, from north-east in March and from north-west in January–February and October–December.

Birds

(Based mainly on the *District Gazetteer*, 1911, Whistler, 1935 and Salim Ali, 1946)

Purnea District with its large number of marshes and slow-flowing streams abounds in fish and aquatic plants. For feeding on them, lots of birds visit Purnea. Damoiselle Crane, European Swallow, pale Harrier, Sand-Piper, Common Teal, several geese and ducks, the Grey, Yellow and Common Wagtail and others visit Purnea in the winter. These come from north and central Asia and from the Himalayas where the winter conditions are very severe. The Wood-snipe and Yellow Wagtail migrate further south but visit Purnea on their return journey in March. The Large Wagtail, Black-headed Oriole, Pea-fowl, Jungle-fowl, Whistling Teal, Bengal Floriken, Likh Floriken, Common Sand-grouse, Rain-quail, Button Quail, Rock Pigeon, Cuckoo, Hawk-cuckoo, Ibis, Curlew, Rail, Black Partridge, Green Pigeon, Comb Duck and others come from the sub-Himalayan tracts and the neighbouring states of Bengal, Assam, Uttar Pradesh and Orissa during and after the rainy season. The Plaintive Cuckoo and many others come in March from the Deccan Peninsula and further south.

Conditions that Favour Introductions

The introduction of such a large number of plants in Purnea District within such a short space of time has possibly been due to the creation in several ways of virgin soils and open areas, places that offer facilities of lodgement to the new arrivals.

The to-and-fro movement of the Kosi River covers large areas of land with sand and coarse silt. During floods, the three rivers, particularly the Kosi, inundate large areas in South Purnea and in the Purnea Town and, on receding, leave it covered with a layer of silt. In the portions kept open by cultivation, there is no question of any competition of the new arrivals with the original vegetation. Even the uncultivated parts, being covered with new layers of silt, offer place for landing. The dry beds of the wide and shallow Kosi River and the newly formed islands, offer good places for lodgement to the new species. All the three rivers, during floods, cause erosion on one bank and deposition on the other. Thus both banks are kept as open areas. Excessive grazing in the grass-lands, particularly, the scraping away of doob-grass by man, and excessive cutting in the scrub-jungles and forests exposes the soil. The torrential rains wash away the soil and form ravines and gulleys on which some of the new arrivals can settle. The erosion by wind, as in Araria area, exposes the lower layers of soil; these also form open areas for the new plants.

Possible Sources

The possible sources of these newly introduced plants in Purnea District have been the following:

1. Nepal Terai, Darjeeling Terai or Sikkim Terai for:

Ludwigia prostrata Roxb., *Aegenetia pedunculata* (Roxb.) Wall., *Asystasia macrocarpa* Nees., *Alisma reniforme*, Don,

Peperomia pellucida (Linn.) H. B. & K. (*vide* Haines, 1921–25).

Staurogyne glauca O. Ktz., *Diplacrum caricinum* R. Br., *Pilea peploides* Hook. & Arn. (*vide* Hooker f., 1872–97).

2. The lower Himalayas or Nepal for:

Vitis lanata Roxb., *Veronica anagallis* Linn. (*vide* Hooker f., 1872–97). *Urtica parviflora* Roxb., *Derris scandens* (Roxb.) Benth. (*vide* Burkill, 1910).

3. Assam, Sikkim, or Abor for:

Ceratophyllum demersum Linn., *Urtica parviflora* Roxb. (*vide* Burkill, 1924), *Urtica parviflora* Roxb. (*vide* Smith & Cave, 1911 and Smith, 1913), *Eriocaulon intermedium* Koern., *Dioscorea oppositifolia* Linn., (*vide* Hooker f., 1872–97), *Staurogyne glauca* O. Ktz. (*vide* Kanjilal, Kanjilal and Das, 1934), *Pseudoraphis aspera* (Koen.) Pilger., *Lolium perenne* Linn. (*vide* Bor, 1940).

4. North Bengal for:

Cyperus cephalotes Vahl., *Veronica anagallis* Linn., *Aegenetia pedunculata* (Roxb.) Wall., *Derris scandens* (Roxb.) Benth., *Neptunia oleracea* Lour., *Myriophyllum indicum* Willd., *Sphenoclea zeylanica* Gaertn., *Ceratophyllum demersum* Linn., *Lagarosiphon alternifolia* (Roxb.) Druce, *Alisma reniforme* Don, *Aponogeton crispum* Thunb., *Diplacrum caricinum* R. Br. (*vide* Prain, 1905).

5. Bengal in general for:

Eichhornia crassipes Solms. (*vide* Biswas and Calder, 1937), *Vitis lanata* Roxb., *Evolvulus nummularius* Linn., *Cyperus kyllinga* Endl., *Pseudoraphis aspera* (Koen.) Pilger, *Brachiaria setigera* (Retz.) Hubbard, *Spirodela polyrrhiza* (Linn.) Schleid., *Dioscorea oppositifolia* Linn. (*vide* Prain, 1903).

6. Uttar Pradesh or its Terai for:

Derris scandens (Roxb.) Benth. (*vide* Kanjilal, 1933), *Lagarosiphon alternifolia* (Roxb.) Druce, *Sphenoclea zeylanica* Gaertn., *Neptunia oleracea* Lour., *Veronica anagallis* Linn., *Aponogeton crispum* Thunb., *Cyperus kyllinga* Endl. (*vide* Duthie, 1903–29), *Alternanthera echinata* Sm. (*vide* Raizada, 1950, and Srivastava, 1955 *b*).

7. The Madhya Pradesh for:

Aponogeton crispum Thunb. (*vide* Haines, 1921—25).

8. Orissa for:

Cyperus polystachyos Rottb., *Cyperus cephalotes* Vahl. (*vide* Haines, 1921–25).

9. The Deccan, Madras Presidency or the Eastern Ghats for:

Lagarosiphon alternifolia (Roxb.) Druce, *Spirodela polyrrhiza* (Linn.) Schleid., *Pseudoraphis aspera* (Koen.) Pilger, *Ludwigia prostrata* Roxb., *Aponogeton crispum* Thunb., *Cyperus cephalotes* Vahl., *Cyperus kyllinga* Endl., *Diplacrum caricinum* R. Br., *Lolium perenne* Linn. (*vide* Gamble, 1918–35), *Lagarosiphon alternifolia* (Roxb.) Druce, *Vitis lanata* Roxb. (*vide* Haines, 1921–25), *Cyperus polystachyos* Rottb., *Brachiaria setigera* (Retz.) Hubbard, *Solanum pubescens* Willd., *Nesæa lanceolata* Koehne, *Plectronia parviflora* Bedd., *Eriocaulon intermedium* Koern, *Heliotropium subulatum* Hochst. (*vide* Hooker f., 1872–97).

Summary

The virgin soils and open areas of the Purnea District that are being formed in various ways have invited plants from outside to settle on them. The larger number of these have been brought by water, birds and wind from the adjoining states. A few have been brought by birds even from distant lands. In this way 36 plants have been introduced in the Purnea District within the last 30 years or so. The progressive desiccation of the district has made the hardier plants from the western districts to come and settle down here.

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APPENDIX I

A complete list of plants collected so far from the Purnea District, arranged in ecological zones. An arrow mark after the name indicates that the plant occurs in the next higher zone also. An asterisk before the name indicates that the plant is being recorded for the first time from Purnea, and a dagger before the name means that it is a new record for Bihar.

1. Aquatic and Amphibious Plants

**Nymphæa pubescens* Willd.
**Nymphæa esculenta* Roxb.
Euryale ferox Salisb.
Pentapetes phœnicea L.
**Melochia corchorifolia* L.
**Corchorus capsularis* L.
Corchorus olitorius L.
**Aeschynomene indica* L.
Aeschynomene aspera L.
†Neptunia oleracea Lour.
†Myriophyllum indicum Willd.
**Rotala rotundifolia* Koehne.
**Rotala indica* (Willd.) Koehne.
**Rotala leptopetala* Koehne.
**Ammannia pygmæa* Kurz.
**Ammannia baccifera* L.
†Nesæa lanceolata Koehne.
Jussiæa repens L.
**Jussiæa suffruticosa* L.—
Jussiæa erecta L.—
**Ludwigia parviflora* Roxb.—
†Ludwigia prostrata Roxb.—
Trapa bispinosa Roxb.
Oenanthe benghalensis Benth.
Adenostemma lavenia (Linn.) O. Ktz.
**Cæsulia axillaris* Roxb.
**Enhydra fluctuans* Lour.
†Sphenoclea zeylanica Gaertn.
**Limnanthemum indicum* (Linn.) Griseb.
**Limnanthemum cristatum* (Roxb.) Griseb.
Hydrolea zeylanica (Linn.) Vahl.
**Ipomæa aquatica* Forsk.
**Bacopa monnieri* (Linn.) Pennell.
Limnophila conferta Benth.
**Limnophila indica* (Linn.) Druce.
Limnophila heterophylla Benth.
Limnophila diffusa Benth.
Limnophila sessiliflora (Vahl.) Blume.
†Veronica anagallis L.
Utricularia stellaris Linn. f.
**Utricularia flexuosa* Vahl.
Hygrophila polysperma (Roxb.) T. Anders.—
**Asteracantha longifolia* (Linn.) Nees.—
Lippia geminata H. B. & K.—
Achyranthes aquatica R. Br.
Alternanthera sessilis (Linn.) R. Br.
**Polygonum orientale* L.
**Polygonum limbatum* Meissn. ?
Polygonum glabrum Willd.
Polygonum lanigerum R. Br.
Polygonum minus Huds.
Polygonum barbatum L.
Polygonum stagnium Ham.
Polygonum rottleri Roth.
Polygonum hydropiper L.
Polygonum prætermissum Hook. f.
†Ceratophyllum demersum L.
Alisma plantago L.
†Alisma reniformis Don.
Sagittaria sagittifolia L.
Sagittaria guayanensis H. B. & K.
**Butomopsis lanceolata* Kunth.
**Aponogeton natans* (Linn.) Engler.
†Aponogeton crispum Thunb.
**Potamogeton crispus* L.
**Potamogeton pectinatus* L.
Naias Kurziana Rendle.
**Naias graminea* Del.
**Hydrilla verticillata* (Linn. f.) Presl.
†Lagarosiphon alternifolius (Roxb.) Druce
**Vallisnaria spiralis* Linn.
Ottelia alismoides (Linn.) Pers.
**Pistia stratioides* L.
†Spirodela polyrrhiza Schleid.
**Spirodela oligorrhiza* Hegelm.
Wolffia arrhiza Wimm.
†Cyperus cephalotes Vahl.
Cyperus platystylis R. Br.
**Cyperus tenuispica* Steud.
**Cyperus distans* Linn.f.
**Cyperus exaltatus* Retz. var. *amœna*
†Cyperus polystachyos Rottb.
**Cyperus stramineus* Clarke.
**Cyperus latespicatus* Boeck.
**Cyperus sanguinolentus* Vahl.
**Cyperus pumilus* Linn.
Cyperus cyperoides (Linn.) O. Ktz.
Cyperus compactus Retz.
**Eleocharis capitata* R. Br.
Eleocharis atropurpurea Kunth.
**Eleocharis palustris* R. Br.
**Eleocharis chætaria* Roem. & Schult.
**Fimbristylis miliacea* Vahl.—
**Fimbristylis quinqueangularis* Kunth.
**Fimbristylis thomsoni* Boeck.

Fimbristylis schœnoides Vahl.
**Fimbristylis bis-umbellata* (Forsk.) Baheni.
**Fimbristylis podocarpa* Nees.
**Fimbristylis diphylla* (Retz.) Vahl. var. *pluri-aristata* Clarke.
**Fimbristylis annua* Roem. & Schult.
Fimbristylis tetragona R. Br.
Fimbristylis dispacea Benth.
**Fimbristylis squarrosa* Vahl.
Bulbostylis barbata Kunth.—
**Bulbostylis capillaris* Kunth.
**Scirpus squarrosus* Linn.
**Scirpus articulatus* Linn.
**Scirpus grossus* Linn. f.
**Scirpus supinus* L.
Phragmites maxima Chiovenda.
Oryza sativa L.
Leersia hexandra Swartz.
**Hygroryza aristata* (Roxb.) Nees.
**Sacciolepis myosuroides* (R. Br.) A. Camus.
Sacciolepis interrupta (Willd.) Stapf.
Panicum repens Linn.
**Panicum paludosum* Roxb.
†*Pseudoraphis aspera* (Koen.) Pilger.
Paspalum scrobiculatum Linn.—
**Paspalidium punctatum* (Burm.) A. Camus.—
**Ischæmum rugosum* Salisb.—
Vetiveria zizanioides (Linn.) Stapf.—
Hemarthria compressa (Linn. f.) R. Br.
**Coix lachryma-jobi* L.
Coix gigantea Roxb.
†*Eriocaulon intermedium* Koern.
**Eriocaulon cinerum* R. Br.
**Eriocaulon soleyanum* Royle.
Eriocaulon quinqueangulare Linn.
**Cyanotis axillaris* Roem. & Schult.—
Juncus prismatocarpus R. Br.
**Monochoria hastata* Solms.
**Monochoria vaginalis* Presl.
†*Eichhornia crassipes* Solms.
**Ceratopteris thalictroides* Brong.
Salvia cucullata Roxb.

2. Plants of the Low Grass-Lands

Stellaria wallichiana Haines.
Polycarpon indicum (Retz.) Merrill.
Phyllanthus urinaria L.
**Phyllanthus simplex* Retz.—
**Phyllanthus niruri* L.
Phyllanthus debilis Ham.
Smithia sensitiva Ait.
Potentilla supina L.
Drosera burmannii Vahl.
**Centella asiatica* (Linn.) Urban.
**Hydrocotyl sibthorpoides* Lamk.
Dentella repens (Linn.) Forst.
Oldenlandia scandens K. Schum.
Oldenlandia diffusa Roxb.
Oldenlandia gracilis DC.
**Oldenlandia paniculata* L.
**Gnaphalium luteo-album* L.
**Gnaphalium indicum* L.
**Gnaphalium pulvinatum* Delile.
**Chrysanthellum indicum* DC.
Cotula hemispherica Wall.
Centipeda minima (Linn.) A. Br. & Aschers.
**Launea nudicaulis* Hook. f.
**Launea asplenifolia* DC.
Stylidium kunthii Wall.
**Lobelia alsinoides* Lamk.
Lobelia terminalis Clarke.
Lobelia affinis Wall.
Wahlenbergia gracilis Schrad.
Androsace saxifragæfolia Bunge.
**Anagallis arvensis* L.
**Anagallis pumila* Swartz.
**Exacum pedunculatum* L.
Exacum tetragonum Roxb.
Swertia angustifolia Buch-Ham. var. *pulchella* Burkill.
**Canscora diffusa* R. Br.
**Canscora decurrens* Dalz.
Hoppea dichotoma Willd.
Merremia vitifolia (Burm. f.) Hallier.
Mazus japonicus (Thunb.) O. Ktz.
**Bacopa hamiltoniana* (Benth.) Wetts.
Adenosma capitatum (Benth.) Hance.
Lindernia hirta (Cham. & Sch.) Pennell.
Lindernia crustacea (Linn.) F. Muell.
Lindernia cordifolia (Colsm.) Merrill.
Lindernia verbenæfolia (Colsm.) Pennell.
**Lindernia ciliata* (Colsm.) Pennell.
**Lindernia anagallis* (Burm.) Pennell.
**Lindernia pyxidaria* All.
Lindernia parviflora (Roxb.) Haines.
Centranthera nepalensis D. Don.
Centranthera hemifusa Wall.
Striga asiatica (Linn.) O. Ktz.
Aegenetia indica Linn.
†*Aegenetia pedunculata* (Roxb.) Wall.
**Staurogyne glutinosa* O. Ktz.
†*Staurogyne glauca* O. Ktz.
Cardenanthera triflora Buch.-Ham.
**Justicia quinqueangularis* Koen.
Justicia peploides T. Anders.
**Justicia diffusa* Willd.
**Justicia simplex* Don.
**Phyla nodiflora* (Linn.) Green.
Dysophila cruciata Benth.
Dysophila verticillata Benth.
Dysophila crassicaulis Benth.
Salvia plebeia R. Br.
**Meriandra benghalensis* Benth.
**Nepeta hindostana* (Roth.) Haines.
Celosia argentea Linn.
**Digera muricata* (Linn.) Mart.
†*Alternanthera echinata* Sm.

Rivina lævis L.
Polygonum chinensis L.
Rumex nigricans Hook. f.
**Cannabis sativa* L.
†*Urtica parviflora* Roxb.
Pilea scripta Wedd.
†*Pilea peploides* Hook. & Arn.
**Pouzolzia zeylanica* (Linn.) Benn.
**Pouzolzia pentandra* Benn.
**Cyperus iria* L.
Cyperus cuspidatus H. B. & K.
**Cyperus difformis* L.
Cyperus niveus Retz.—
Cyperus amabilis Vahl.—
**Cyperus nutans* Vahl.
**Cyperus rotundus* Linn.
**Cyperus triceps* (Rottb.) Endl.
†*Cyperus kyllinga* Endl.
†*Diplacrum caricinum* R. Br.
**Fuirena glomerata* Lamk.
**Eragrostis japonica* Trin.—
Eragrostis unioloides (Retz.) Nees.
**Eragrostis gangetica* (Roxb.) Steud.
**Eragrostis cilianensis* (All.) Link.
**Eragrostis pilosa* (Linn.) Beauv.
Eragrostiella bifaria Bor.—
Elytrophorus spicatus (Willd.) A. Camus.
Cynodon dactylon (Linn.) Pers.
Eleusine indica (Linn.) Gaertn.
**Dactyloctenium ægyptium* (Linn.) Beauv.
**Sporobolus tremulus* Kunth.
**Echinochloa crus-galli* (Linn.) Beauv.
**Oplismenus burmanni* (Retz.) Beauv.
†*Brachiaria setigera* (Retz.) Hubbard.
Eriochloa procera (Retz.) Hubbard.
**Saccharum spontaneum* Linn.
**Eriantha benghalensis* (Retz.) Hubbard.
Apocopsis paleaceous (Trin.) Host.
†*Lolium perenne* L.
Apluda mutica L. var. *eumutica* (Linn.) Pilger.
**Commelina nudiflora* L.
**Commelina salicifolia* Roxb.
**Commelina benghalensis* L.
Murdannia spiratum (Linn.) Bruckner.
Murdannia nudiflorum (Linn.) Bruckner.
Murdannia vaginatum (R. Br.) Bruckner.
Floscopa scandens Lour.

3. Plants of the High Grass-Lands

**Cleome viscosa* Linn.
**Gynandropsis gynandra* (Linn.) Briq.
**Sida veronicæfolia* Lamk.
**Sida glutinosa* Cav.
**Sida cordifolia* Linn.
Sida spinosa Linn.
Hibiscus pungens Roxb.
**Hibiscus panduræformis* Burm.
**Abelmoschus manihot* (Linn.) Medik.
**Triumfetta annua* Linn.
**Triumfetta pentandra* A. Rich.
Triumfetta rhomboidea Jacq.
**Corchorus trilocularis* L.
**Corchorus fascicularis* Lamk.
**Corchorus æstuans* Linn.
**Euphorbia granulata* Forsk.
Euphorbia parviflora Linn.
Euphorbia thymifolia L.
**Crotalaria acicularis* Buch-Ham.
**Crotalaria prostrata* Roxb. var. *lævis* Haines.
**Crotalaria tetragona* Roxb.
**Medicago lupulina* L.
**Medicago denticulata* Willd.
**Indigofera linifolia* Retz.
**Indigofera sumatrana* L.
**Indigofera hirsuta* Linn.
**Uraria picta* (Jacq.) Desv.
**Uraria pulchra* Haines.
**Uraria lagopodioides* Merr.
**Uraria alopecuroides* Wight.
**Alysicarpus bupleurifolius* (Linn.) DC.
**Alysicarpus rugosus* (Willd.) DC.
**Alysicarpus monilifer* DC.
**Alysicarpus hamosus* Edgew.
**Desmodium triflorum* (Linn.) DC.
Desmodium triangularis (Retz.) Santapau
Desmodium triquetrum (Linn.) DC.
Desmodium motorium Merr.
Desmodium gyroides (Roxb.) DC.
**Phaseolus trilobatus* Ait.
**Phaseolus aconitifolius* Jacq.
**Cassia occidentalis* Linn.
Cassia leschaultiana DC.
**Mimosa pudica* Linn.
**Melothria zehneroides* Haines.—
Trachyspermum roxburghii (DC.) Sprague.
**Oldenlandia pumilla* DC.
**Oldenlandia corymbosa* Linn.
**Oldenlandia dichotoma* Koen.
**Borreria stricta* (Linn. f.) Schum.
**Borreria hispida* (Linn.) Schum.
**Elephantopus scaber* L.
**Erigeron asteroides* Roxb.
Blumea atropurpurea Haines.
Blumea lacera DC.
Blumea virens DC.
Bidens biternata (Lour.) Merr. & Sherff.
**Cirsium avense* (Linn.) Scop.
Artemisia caruifolia Buch-Ham.
Sausurea affinis Spr.
**Youngia japonica* (Linn.) DC.
Lactuca polycephala DC.
Sonchus arvensis L. var. *glaber* Haines.
**Lochnera pusilla* Schum.
**Heliotropium indicum* L.
Heliotropium strigosum Willd.
†*Heliotropium subulatum* Hochst.
**Heliotropium ovalifolium* Forsk.

Evolvulus alsinoides Linn.
†*Evolvulus nummularius* Linn.
Ipomœa cæspitosa Haines.
Merremia chryseoides Hallier. f.
**Scoparia dulcis* L.
Striga euphrasioides Benth.
Dipteracanthus prostratus (Poir.) Nees.
**Peristrophe bicalyculata* (Retz.) Nees.
**Dicliptera roxburghiana* Nees.
Clerodendron viscosum Vent.
**Ocimum americanum* L.
**Ocimum basilicum* L.
**Hyptis suaveolens* (Linn.) Poit.—
**Pogostemon plectranthoides* Desf.
Plectranthus ternifolius Don.
**Leonurus sibericus* L.
Leucas lavandulæfolia Rees.
**Leucas cephalotes* Spreng.
Pupalia atropurpurea Moq.
**Aerva lanata* (Linn.) Juss.
**Aerva sanguinolenta* (Linn.) Bl.
**Achyranthes aspera* Linn.
Chenopodium album L.
**Chenopodium murale* L.
**Chenopodium ambrosoides* L.
**Eragrostis plumosa* Link.
**Eragrostis coarctaca* Stapf.
**Chloris incompleta* Roth.
Chloris barbata Sw.
**Sporobolus diander* Beauv.
**Aristida adscenscionis* L.
Arundinella benghalensis Druce.
**Digitaria ascendans* (H.B. K.) Henrard.
Perotis indica (Linn.) O. Ktz.
**Oplismenus compositus* (Linn.) Beauv.
Isachne miliacea Roth.
Isachne dispar Trin.
**Isachne albens* Trin.
Setaria italica (Linn.) Beauv.
**Panicum humile* Nees. ex. Steud.
Echinochloa colona (Linn.) Link.
Panicum trypheron Schult.
Paspalidium flavidum (Retz.) A. Camus.
Erianthus arundinaceus (Retz.) Jeswait.
Narenga porphyrocoma (Hance.) Bor.
Saccharum fastigiatum Steud.
**Imperata cylindrica* (Linn.) Beauv.
Eulalia cummingii (Nees.) A. Camus.
**Eulalia binata* (Retz.) Hubbard.
**Bothriochloa pertusa* (Willd.) A. Camus.
**Chrysopogon aciculatus* (Retz.) Trin.
**Dichanthium caricosum* (Linn.) A.Camus.
**Dichanthium annulatum* (Forsk.) Stapf.
Schizachyrium brevifolium (Sw.) Nees.
Cymbopogon flexuous (Nees.) Wats.
**Themeda quadrivalvis* (Linn.) O. Ktz.
Themeda strigosa (Buch-Ham.) A. Camus.
Themeda arundinacea Ridley.
**Ophiuros megaphyllus* Stapf.
**Apluda mutica* L. var. *aristata* (L.) Pilger.
**Hackelochloa granularis* (Linn. f.) O. Ktz.
Murdannia scapiflorum (Wight) Bruckner.
**Habenaria constricta* Hook. f.
Adenostylis strateumatica (Linn.) Ames.
Zeuxine membranacea Lindl.

4. Plants of the Scrub-Jungles

**Annona squamosa* L.—
Flacourtia sepiaria Roxb.
**Flacourtia indica* Merr.
**Flacourtia jangomas* (Lour.) Raeusch.
**Salmalia malabarica* (DC.) Schott. & Endl.
Grewia sepiaria Roxb.
**Jatropha curcas* Linn.
**Jatropha gossypifolia* Linn.
Bridelia stipularis (Linn.) Blume.
Bridelia tomentosa (Linn.) Blume.
**Kirganellia reticulata* (Poir.) Baill.—
**Melanthesa turbinata* (Koen.) Wight.—
Glochidion multiloculare Muell-Arg.
Aporosa dioica (Roxb.) Muell-Arg.
Antidesma ghæsembilla Gaertn.
**Antidesma diandrum* (Roxb.) Roth.
Euphorbia acaulis Roxb.
**Glycosmis pentaphylla* (Retz.) Correa.—
**Murraya kœnigii* (Linn.) Spreng.
Aegle marmelos (Correa) Tanaka.
Toona ciliata (Roem.)
**Zizyphus mauritiana* Lamk. var. *fruticosa* (Haines) Srivastava.
Zizyphus œnoplia Mill.
Zizyphus rugosa Lamk.
Cayratia trifolia (Linn.) Gagnep.
Abrus lævigatus F. Mey.
Abrus precatorius Linn.
Canavalia virosa (Roxb.) W. & A.
Butea monosperma (Linn.) O. Ktz.
**Mucuna nigricans* (Lour.) Steud.
Erythrina variegata L. var. *orientalis* Merrill.
Dalbergia sissoo Roxb.
**Cæsalpinia spicata* Dalz.
**Cæsalpinia crista* L.
Mimosa himalayana Gamble.
**Acacia arabica* (Lamk.) Willd.
Acacia canescens Grahm.
Acacia concinna (Willd.) DC.
**Acacia catechu* Willd.
Melothria maderaspatensis (Linn.) Cogn.
Bryonia amplexicaule Lamk.
**Momordica charantia* L.
**Momordica dioica* Roxb. ex Willd.
Luffa echinata Roxb.
Luffa graveolens Roxb.
Opuntia monacantha Haw.

**Opuntia dillenii* (Ker-Grawl.) Haw.
**Alangium salvifolium* (Linn. f.) Wang.
Alangium chinensis (Lour.) Merr.
Morinda angustifolia Roxb.
**Randia brandisii* Gamble.
Randia fasciculata DC.
**Pavetta indica* L.
Coffea benghalensis Roxb.
†*Plectronia parviflora* Bedd.
Vangueria spinosa Roxb.—
**Vangueria pubescens* Kurz.
Pæderia fœtida L.
Diospyros montana Roxb.
Symplocos racemosa Roxb.
Ichnocarpus frutescens R. Br.
**Hemidesmus indicus* (Linn.) R. Br.
Cryptolepis buchanani Roem. & Schult.—
Streptocaulon sylvestre Wight.
**Pergularia dæmia* (Forsk.) Blatter & McCann.
Oxystelma esculentum (Linn. f.) R. Br.
Calotropis acia Buch.-Ham.
Cyananchum callialatum Buch.-Ham.
Gymnema sylvestre (Retz.) R. Br.
**Telosma pallida* (Roxb.) Craib.
**Ipomœa muricata* (Linn.) Jacq.
**Ipomœa pes-tigris* L. var. *capitellata* Clarke.
**Ipomœa obscura* (Linn.) Ker-Grawl.
**Merremia emarginata* (Burm. f.) Hallier.
Calystegia hederacea Wall.
Solanum verbascifolium L.—
**Solanum indicum* L.
Solanum torvum Swartz.—
**Martynia annua* Linn.
**Lantana camara* L. var. *aculeata* L.
**Premna flavescens* Buch.-Ham.
Colebrookea oppositifolia Sm.
Deeringia amaranthoides (Lamk.) Merr.
Bœhmeria platyphylla Don.
Bœhmeria scabrella (Roxb.) Gaud.
Streblus asper Lour.
**Ficus retusa* L.
Ficus heterophylla Linn. f.
**Phœnix sylvestris* (Linn.) Roxb.
**Borassus flabellifer* L.
Dioscorea puber Blume.
Dioscorea hispida Dennst.
Dioscorea bulbifera L.
Alpinia allughas Rosc.—
Lygodium flexuosum Sw.
Lygodium japonicum Sw.
Lygodium microphylla Sw.
Pteris longifolia L.
Other ferns.

5. Plants of the Monsoon Forests

Naravelia zeylanica DC.
Dillenia indica L.
Dillenia pentagyna Roxb.
Michelia champaca L.
Annona reticulata L.
Saccopetalum longiflorum Hook. f. & Arn.
**Cissampelos pareira* Linn.
Stephania hernandifolia (Willd.) Walp.
**Tinospora cordifolia* (Willd.) Miers.
**Tiliacora acuminata* (Lamk.) Miers.
**Cocculus hirsutus* (Linn.) Diels.
Casearia tomentosa Roxb.
Mesua ferrea L.
**Hibiscus lobatus* O. Ktz.
**Pterospermum acerifolium* Willd.
Pterospermum suberifolium Lamk.
Grewia sapida Roxb.
Eleocarpus sphæricus (Gaertn.) Schum.
Eleocarpus serratus L.
Croton oblongifolius Roxb.
**Trewia polycarpa* Benth.
Mallotus repandus Muell-Arg.
Baliospermum montanum Muell-Arg.
Sapium sebiferum Roxb.
**Tragia involucrata* L.
Putranjiva roxburghii Wall.
**Murraya paniculata* (Linn.) Jack.
Aphanamixis polystachya (Wall.) Parker.
Natsium herpeticum Buch.-Ham.
Cissus adnata Roxb.
Cissus repanda Vahl.
†*Vitis lanata* Roxb.
Ampelocissus latifolia (Roxb.) Planch.
Ampelocissus tomentosa Planch.
Tetrastigma bracteolata Planch.
Tetrastigma thomsoniana Planch.
Leea crispa Linn.
Leea macrophylla Roxb. ex. Hormen.
Lannea coromandeliana (Houst.) Merrill.
**Desmodium pulchellum* (Linn.) Benth.
**Desmodium laxiflorum* DC.
**Desmodium gangeticum* (Linn.) DC. var. *maculatum* Baker.
Puereria phaseoloides Benth.
**Mucuna prurita* Hook. f.
**Derris cuneifolia* Benth.
†*Derris scandens* (Roxb.) Benth.
Mezoneuron cucullatum (Roxb.) W. & A.
Entada phaseoloides (Linn.) Merr.
**Acacia farnesiana* (Linn.) Willd.
Albizzia lucida (Roxb.) Benth.
Albizzia lebbek (Linn.) Benth.
Rosa involucrate Roxb.
**Terminalia bellerica* (Gaertn.) Roxb.
Syzygium operculatum Gamble.
Syzygium jambos (Linn.) Alston.
Barringtonia acutangula Gaertn.
Osbeckia rostrata Don. var. *pulchella* Benth.
Osbeckia nepalensis Hook. f.
Trichosanthes bracteata (Lamk.) Wight.
**Trichosanthes dioica* Roxb.

Coccinia cordifolia Cogn.
Trevesia palmata Vis.
Hymenodicyton excelsum (Roxb.) Wall.
Hyptianthera stricta W. & A.
Ardisia solenacea Roxb.
**Madhuka indica* Gmel.
**Madhuka butyracea* (Roxb.) McBride.
Malinkara hexandra (Roxb.) Dubard.
Jasminum pubescens (Retz.) Willd.
Ervatamia divaricata (Linn.) Burm.
Alstonia scholaris R. Br.
Buddleia neemda Buch.-Ham.
Ehretia acuminata R. Br.
Ehretia lævis Roxb.
Argyreria roxburghii Choisy.
**Porana paniculata* Roxb.
Calonyction aculeatum (Linn.) Houst.
**Merremia umbellata* (L.) Hallier. f. var. *cochleata* (Haines) Srivastava.
Ipomœa digitata Linn.
Solanum ferox L.
†*Solanum pubescens* Willd.
**Datura stramonium* L.
Stereospermum suaveolens DC.
Strobilanthes scaber Nees.
**Erianthemum nervosum* R. Br.
Barleria strigosa Willd.
†*Asystasia macrocarpa* Nees.
Adhatoda vasica Nees.
Callicarpa tomentosa (Linn.) Murr.
Callicarpa macrophylla Vahl.
**Tectona grandis* Linn. f.
**Vitex negundo* L.
Premna scandens Roxb.
**Premna barbata* Wall.
Premna latifolia Roxb. var. *latifolia* proper.
..........var. *mucronata* Clarke.
.... var. *gamblei* Haines.
**Premna benghalensis* Clarke.
**Gmelina arborea* Roxb.
Clerodendron serratum (Linn.) Moon.
Clerodendron indicum O. Ktz.
**Caryopteris wallichiana* Schauer.
Anisomeles indica (Linn.) O. Ktz.
Ajuga macrosperma Wall.
Piper betel L.
Piper longum L.
†*Peperomia pellucida* (Linn.) H. B. & K.
**Litsæa glutinosa* (Lour.) C. B. Rose.
Litsæa salicifolia Roxb. var. *laurifolia* Hook. f.
**Dendrophthœ falcata* (Linn. f.) Etting.
**Loranthus globosus* Roxb.
Distemon indicum Wedd.
**Morus indica* L.
Cudrania javanica Trecul.
**Ficus cunia* Ham.
Ficus religiosa L.
**Ficus benghalensis* L.
Ficus lacor Buch.-Ham.
Salix tetrasperma Roxb.
Pothos cathcartii Schott.
**Amorphophallus campanulatus* Bl.
**Sauromatum guttatum* (Wall.) Schott.
**Typhonium trilobatum* Schott.
Remusatia vivipara (Roxb.) Schott.
Colocasia esculenta (Linn.) Schott. var. *illustris* (Engler) Srivastava
.... var *stolonifera* (Haines) Srivastava.
.... var. *rupicola* (Haines) Srivastava.
Alocasia indica Schott.
**Alocasia fornicata* Schott.
Calamus viminalis Willd.
Calamus tenuis Roxb.
Calamus garuga Buch.-Ham.
Pogonatherum paniceum (Lamk.) Hack.
**Smilax prolifera* Roxb.
Dracena angustifolia Roxb.
Crinum asiaticum L.
**Curculigo orchioides* Gaertn.
†*Dioscorea oppositifolia* L.
Dioscorea glabra Roxb.
**Dioscorea belophylla* Voight.
Dioscorea wallichii Hook. f.
Dioscorea alata L.
**Dioscorea pentaphylla* L.
Burmannia cœlestis Don.
**Curcuma zeodaria* Rosc.
**Hedychium coronarium* Koenig.
**Hedychium stenopetalum* Lodd.
Amomum dealbatum Roxb.
**Zingiber casumnar* Roxb.
Costus speciosus (Koen.) Smith.
Alpinia allughas Rosc.
**Alpinia galanga* Sw.
**Alpinia malaccensis* Rosc.
**Vanda parviflora* Lindl.
**Vanda tessellata* Hook.
Nephrodium molle Desv.
Diplazium esculentum Sw.
Selaginella spp.
Ophioglossum spp.

6. Plants near Human Habitations

(Ruins, dust-heaps, along roads, and in cultivated fields)

**Argemone mexicana* L.
Withania somnifera Dunal.
Lindenbergia indica (L.) O. Ktz.
Ocimum sanctum L.
Rumex vesicarius L.
Celtis tetrandra Roxb.
†*Croton bonplandianum* Baill.
†*Gomphrena celosioides* Mart.
Ficus spp.
Pandanus fœtidus Roxb.
**Pandanus tectorius* Sol.
†*Lolium temulentum* L.
Pteris longifolia L.

APPENDIX II

An ecological analysis of the Purnea flora

Ecological Category	Number of plants reported in Haines' book from Purnea	Number of plants reported in Haines' book from districts other than Purnea	Number of plants new to the State
Aquatic and Amphibious plants	53	54	16
Plants of the Low Grass-lands	59	55	9
Plants of the High Grass-lands	50	70	2
Plants of the Scrub-Jungles	55	37	1
Plants of the Monsoon Forests	102	56	5
Plants found near Human Habitations	9	2	3
	328	274	36

THE CLAVARIACEAE OF THE MUSSOORIE HILLS—IV

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This paper is intended to record more Clavariaceæ from the Mussoorie Hills (5,000–7,000 ft. altitude in the North-Western Himalayas), as a part of the study of the Fungal Flora of that region undertaken by the senior author and his students (Thind and Anand, 1956; Corner, Thind and Anand, 1956; and Thind and Anand, 1956). All the seven Clavarias described in this paper belong to the Clavaria series. Six of these are new records for India whereas *Clavulina cristata* (Fr.) Schroet. var. *brunneola* var. nov. is described here as a new variety. All the specimens are deposited in the Herbarium of the Panjab University.

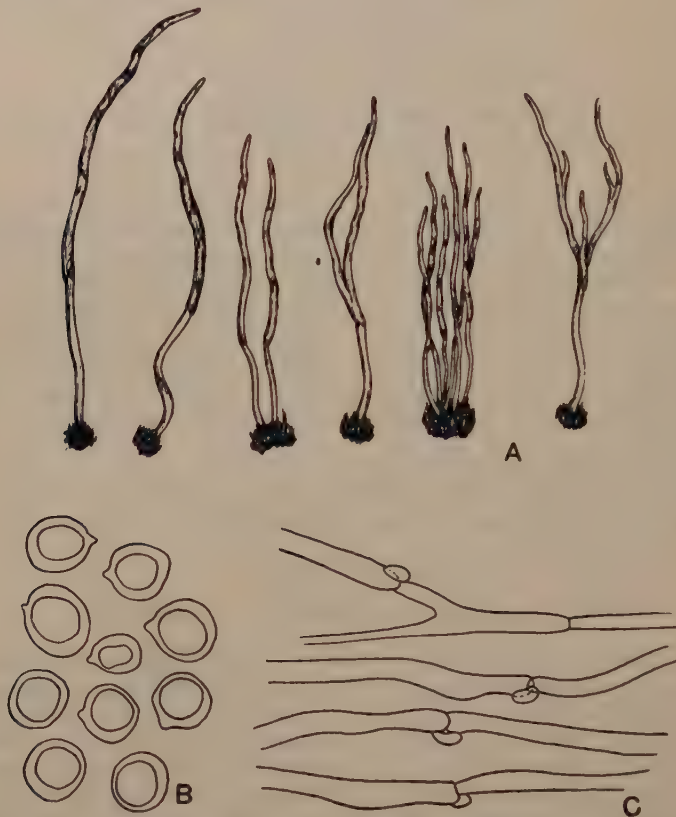
The classification as proposed by Corner, 1950, in his Monograph of Clavaria and allied genera, has been followed in the present series.

Clavaria Series

22. *Clavulina amethystinoides* (Pk.) Corner

Fructifications gregarious, solitary, mostly singly, sometimes in cæspitose clusters of 2–4 or more clubs, erect, small to medium-sized, slender, radial, trunk present, mostly simple but there is marked tendency towards slight or sparse branching, fleshy, smooth, glabrous, violet, 5–8 cm. tall, individual clubs up to 4 mm. broad. Trunk sharply differentiated by its brown colour, cylindrical, sometimes flattened and twisted, solid, 1–2 cm. long and up to $2 \cdot 5$ mm. broad. Clubs mostly simple, sometimes sparsely branched up to a maximum of four times. The clubs may look almost unbranched except for one or two short antler branches, at other times a club may divide only once into two branches (usually unequal) which may soon fuse together for the most part or only towards the top, thus giving a marked grooved appearance. In some cases a club may be divided into 2–4 equal branches having a common stalk below. Thus the sparse branching is of irregular type or irregularly dichotomous. Apices are pointed or blunt. Taste and smell inparticular. *Hymenium* spread all over except the trunk, stratose, 40–53 μ broad. *Basidia* clavate, $7–10 \cdot 5\ \mu$ broad. Sterigmata 2, $3 \cdot 5–12\ \mu$ long. *Basidiospores* subhyaline, globose, subglobose, or sometimes pyriform, papillate, uniguttate, guttule large, occupying more than half of the spore cavity, $9–12 \cdot 3 \times 8 \cdot 8–10 \cdot 5\ \mu$. *Hyphæ* monomitic, hyaline, branched, parallel, thin-walled, inflated, septate, septa at short intervals, thus hyphæ with short, broad, inflated cells, branches of hyphæ narrow and not inflated, clamped, clamps abundant,

ends of hyphal cells often gliding over one another, sub-hymenial hyphæ 5–8 μ broad, context hyphæ 5–12 μ broad, hyphal cells up to 176 μ long (Text-Fig. 1, A–C).



TEXT-FIG. 1. *Clavulina amethystinoides* (Pk.) Corner, A. Fructifications, ×1. B. Basidiospores, ×880. C. Hypnæ with clamps, ×380.

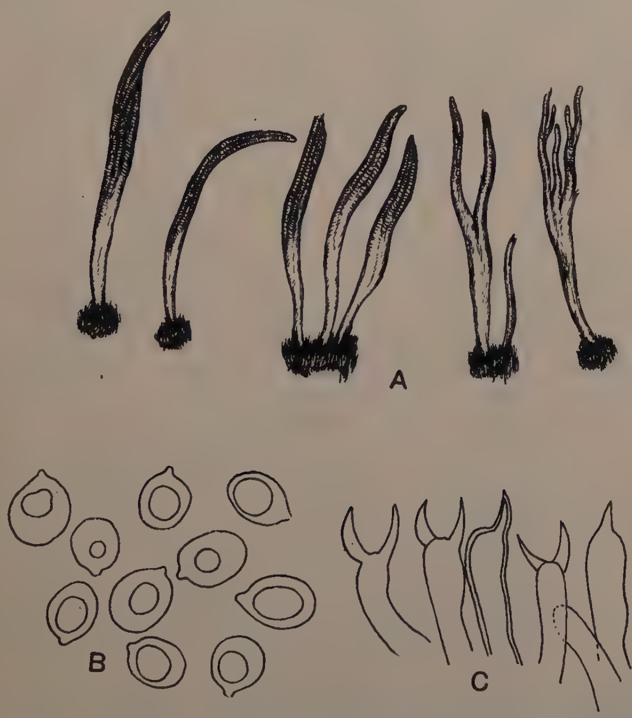
Collected on soil amid mosses, Dhobi Khud, Mussoorie, August 8, 1953, 53.

This collection undoubtedly belongs to *Clavulina amethystinoides* (Pk.) Corner and is marked by simple, or sparsely branched, violet-coloured fructifications. However, its spores are larger than usual, being 9–12·3 × 8·8–10·5 μ against 7–10 × 6–8 μ as reported for *C. amethystinoides* (Corner, 1950). This larger spore size, together with the violet colour (of the fruit bodies), fits *Clavulina amethystina* (Fr.) Donk, but the latter has always profusely branched fruit bodies.

23. *Clavulina cristata* (Fr.) Schroet.

Fructifications solitary, gregarious, cæspitose, erect, medium-sized, radial to flattened, trunk usually present, simple to sparsely branched,

fleshy, smooth, glabrous, white or cream coloured, up to 6·8 cm. tall, cæspitose clusters up to 1·5 cm. broad, individual clubs up to 0·8 cm. broad. Trunk indistinct, lighter coloured or concolorous, narrower than the clubs above, usually about one-third of the total length of the fructifications, or absent. Fructifications simple, or very sparsely branched, usually only once, solid, narrow below and broader above, longitudinally grooved, flattened, and wrinkled when old, often spathulate or cerebriform, branches often remain antler-like. Apices subacute to rounded. Flesh concolorous or lighter. Taste and smell inparticular. Rhizomorphic mycelial strands abundantly given out from the bases of the fructifications. *Hymenium* spread all over except near the base, thickening, 38–105 μ thick. *Basidia* subclavate to cylindrical, 4·2–7 μ broad. Sterigmata 1–2, mostly 2, incurved, 3·5–7 μ long. *Basidiospores* paler yellowish brown, globose to subglobose, papillate, smooth, uniguttate, guttule large and filling one-half to two-third of the spore cavity, 7·6–10·9 $\times$ 7–10·5 μ. *Hyphæ* monomitic, hyaline, branched, thin-walled, inflated, narrow hyphæ uninflated, septate, septa at short intervals, clamped, clamps abundant and present at all septa, H-connections present but rare, 2·8–11·6 μ broad, hyphal cells 38–102 μ long, or even more (Text-Fig. 2, A–C).



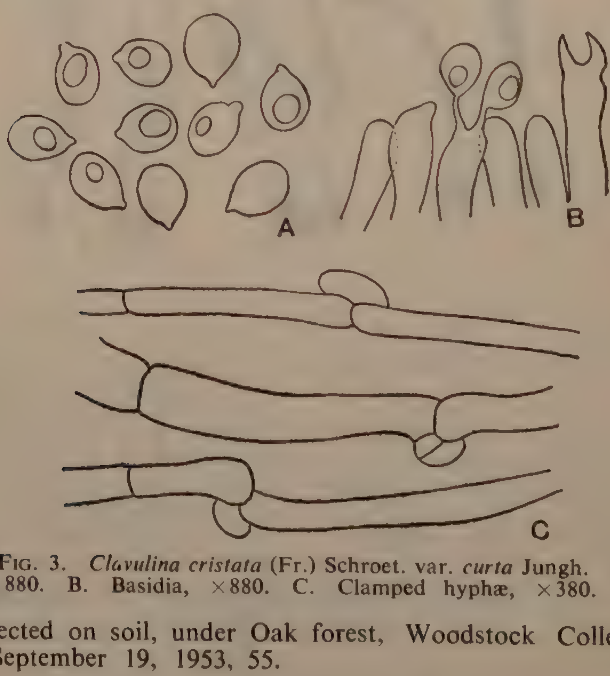
TEXT-FIG. 2. *Clavulina cristata* (Fr.) Schoroet. A. Fructification, ×1. B. Basidiospores, ×880. C. Basidia, ×880.

Collected on soil amid mosses and under Oak forest, Jabbar Khud, Mussoorie, August 17, 1953, 54.

This collection apparently is a simple to sparsely branched form of *Clavulina cristata* (Fr.) Schroet.

24. *Clavulina cristata* (Fr.) Schroet. var. *curta* Jungh.

Fructifications solitary, cæspitose, gregarious, erect, small-sized, radial, trunk invariably present, branched, rarely simple, fleshy, smooth, glabrous, white, 1–4 cm. tall, 0·2–2·3 cm. broad. Trunk white, radial, 4–8 mm. long, up to 4 mm. wide. Branching sparse to profuse, often crowded, irregular, polychotomous below giving rise to several trunk-like primary branches which divide further dichotomously, upper branches usually flattened, sometimes fused with one another, short and stubby. Ultimate branchlets cristate, short, some mere protuberances. Apices blunt and concolorous. Flesh white. Taste and smell inparticular. *Hymenium* spread all over except the trunk, 35–60 μ thick. *Basidia* clavate, 4·6–7 μ broad. Sterigmata 2, short, usually incurved like pair of a tong, 4·2–7 μ long. *Basidiospores* hyaline or subhyaline, globose, subglobose, or broadly ellipsoid, papillate, smooth, uniguttate, guttule large and filling one-half, or more, of the spore cavity, 8–10·5 × 7–7·7 μ. *Hyphæ* monomitic, hyaline, branched, thin-walled, inflated, septate, septa at short intervals, clamped, clamps present at all septa, 3·5–9·8 μ broad, hyphal cells 7–10·6 μ long. (Pl. XVIII, Fig. 1; Text-Fig. 3, A–C).



TEXT-FIG. 3. *Clavulina cristata* (Fr.) Schroet. var. *curta* Jungh. A. Basidiospores, ×880. B. Basidia, ×880. C. Clamped hyphæ, ×380.

Collected on soil, under Oak forest, Woodstock College, Mussoorie, September 19, 1953, 55.

Var. *curta* Jungh. represents merely a small state of *Clavulina cristata* (Fr.) Schroet. connecting it with var. *lappa* Karst.

25. *Clavulina cristata* (Fr.) Schroet. var. *brunneola* var. nov.

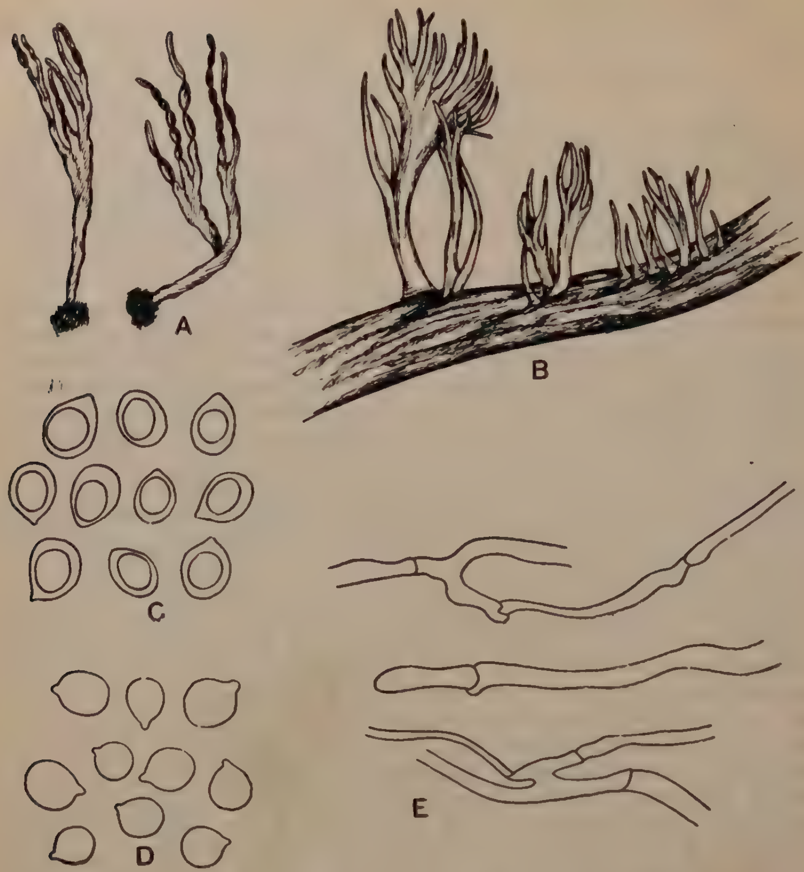
Usque 6·2 × 2·2 cm., solitaria vel cæspitosa vel gregaria, brunneola, laxe ramosa: basidiis secondo septatis: sporis 7–10·5 × 6–8 μ, 1-guttatis: hyphis inflatis, fibulatis: ad terram, Chakrata Toll, Mussoorie, India, September 2, 1953, 56; ad folia emortua, ramulos emortuos et corticum emortuum, Chakrata Toll, Mussoorie, India, September 7, 1953, 57.

Up to 6·2 × 2·2 cm., solitary, or cæspitose and gregarious, brownish, dust-coloured or milk-toffee-coloured, branches lax: basidia secondarily septate after spore discharge: spores 1-guttate, 7–10·5 × 6–8 μ: hyphæ inflated, clamped: on soil, Chakrata Toll, Mussoorie, India, September 2, 1953, 56; on dead leaves, dead twigs and dead bark, Chakrata Toll, Mussoorie, India, September 7, 1953, 57.

Fructifications terrestrial or lignicolous, solitary, or cæspitose and gregarious, erect, small to medium-sized, radial, trunk present, branched, fleshy, smooth, glabrous, brownish, dust-coloured or milk toffee-coloured, up to 6·2 cm. tall and up to 2·2 cm. broad. Trunk up to 1 cm. long and up to 2 mm. broad, cylindrical, concolorous. Branching lax, polychotomous to dichotomous, or irregular, branches unequal, in alternating planes, usually flattened at the point of origin and often twisted due to irregular and spiral flattening, sometimes fused with one another, some branches very small and antler-like. Primary branches up to 2 mm. wide, ultimate branchlets very minute to 2·2 cm. long and usually cristate, apices acute and concolorous. Flesh paler concolorous. Taste and smell inparticular. *Hymenium* spread all over except the trunk, thickening, up to 88 μ broad. *Basidia* clavate, secondarily septate after spore discharge, 5–7 μ broad. Sterigmata usually 2, sometimes 1, incurved, 3·5–7 μ long. *Basidiospores* hyaline to subhyaline, globose, subglobose, or oval to obovate, papillate, papilla eccentric, uniguttate, guttule large and almost completely filling the spore cavity, 6–10·5 × 5·2–7·8 μ. *Hyphæ* monomitic, hyaline, branched, thin-walled, inflated, septate, septa at short intervals, clamped, clamps present at almost all septa, H-connections present, 3·5–14 μ wide, hyphal cells 24–116 μ long (Text-Fig. 4, A–E).

Collected on soil along the eroded slopes of hills, Chakrata Toll, Mussoorie, September 2, 1953, 56. On dead leaves, dead twigs, and dead bark of trees, Chakrata Toll, Mussoorie, September 9, 1953, 57.

These two collections, n. 56 and n. 57, undoubtedly belong to *Clavulina cristata* (Fr.) Schroet. However, their fruit bodies are regularly brownish or milk-toffee-coloured which colour is not reported for *C. cristata* or any if its varieties. Hence these two collections are made a new colour variety—*brunneola* on the basis of their brownish colour. Their spores, especially those of n. 57, are slightly smaller than in *C. cristata* (*C. cristata*, 7–11 × 6·5–10 μ; n. 56, 7·7–10·5 × 7 μ; n. 57, 6–8·6 × 5·2–7·8 μ).



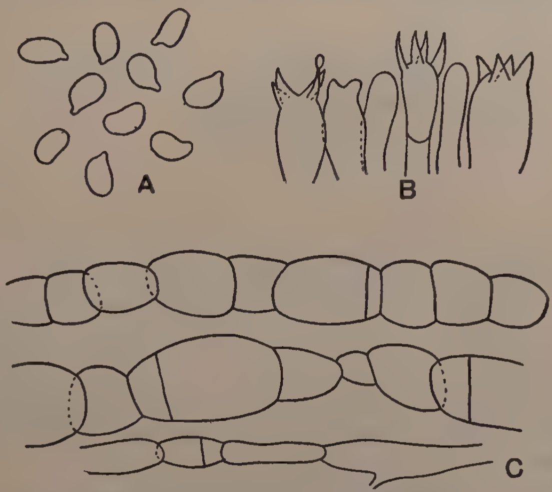
TEXT-FIG. 4. *Clavulina cristata* (Fr.) Schroet. var. *brunneola* var. nov., A. Fructifications of *n.* 56 with twisted branches, ×1. B. Fructifications of n. 57, ×1. C. Basidiospores of n. 56, ×880. D. Basidiospores of n. 57, ×880. E. Hyphæ with clamps and H-connection from n. 57, ×380.

Var. *brunneola* var. nov. as proposed here is easily differentiated from var. *curta* Jungh. and var. *lappa* Karst. (of *C. cristata*) both of which are pure white. It is also easily differentiated from *C. cristata* (n. 54) which is white or cream-coloured as reported in this paper.

26. *Clavaria fumosa* Fr.

Fructifications solitary, densely cæspitose, erect, large-sized, radial, without a trunk, simple, fleshy, brittle, smooth, glabrous, light milk-toffee-coloured, base whitish, up to 12·5 cm. tall and up to 10·5 cm. broad. A large number of clubs arise from a common base. Each club is long, clyindrical, tapering at the top and is unbranched. Individual clubs are up to 3 mm. broad. Some clubs possess a longitudinal groove and are ligulate and hollow. Apices are concolorous and

blunt. Flesh pale concolorous, does not change on bruising. Taste and smell inparticular. *Hymenium* spread all over except the whitish base, compound, up to 56 μ broad. *Basidia* clavate, $5\cdot6$–8 μ broad. Sterigmata 3–4, small, stout, slightly incurved, $1\cdot8$–$4\cdot2$ μ long. *Basidiospores* usually broadly ellipsoid, some slightly allantoid, papillate, hyaline, smooth, aguttate, filled with granular contents, 7–8 $\times$ $2\cdot8$–$6\cdot3$ μ. *Hyphæ* monomitic, hyaline, thin-walled, inflated, some hyphæ very narrow and uninflated, clamps absent, septate, septa at short intervals, also secondarily septate, 5–17 μ wide, hyphal cells small, 4–68 μ long, mostly 8–13 μ long. Hyphæ are short-celled and closely apposed so as to give the appearance of a pseudoparenchyma. The individual hyphal nature is, however, easily revealed by separating them with dissecting needles because the hyphæ are very easily separated from one another (Pl. XVIII, Fig. 2; Text-Fig. 5, A–C).



TEXT-FIG. 5. *Clavaria fumosa* Fr. A. Basidiospores, ×880. B. Basidia, ×880. C. Inflated hyphæ with secondary septa, ×380.

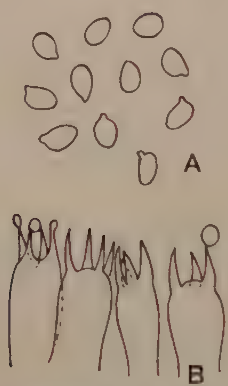
Collected on soil under Oak forest, The Park, Mussoorie, August 31, 1953, 58.

The species is easily recognized by simple, densely cæspitose, light-coloured and large-sized fruit bodies ($-12\cdot5$ cm.) lacking a trunk, aguttate spores filled with granular contents and small-celled inflated hyphæ with secondary septa but without clamps.

27. *Clavaria vermicularis* Fr. var. *gracilis* Bourd. et Galz.

Fructifications solitary, gregarious, cæspitose, erect, medium-sized, radial, trunk present, mostly simple, sometimes sparsely branched, fleshy-brittle, smooth, glabrous, milk white, up to $7\cdot5$ cm. tall, individual clubs up to 2 mm. broad, cæspitose clusters up to 1 cm. broad or slightly more. Trunk white, transluscent or glassy, cylindrical, distinct by its transluscent appearance, about one-fourth of the total

length of the clubs. Clubs mostly simple and cylindrical, sometimes slightly branched, flattened and grooved, branching dichotomous, usually only once, or 1–3 times near the top. Apices acute or subacute and concolorous. Flesh concolorous. Taste and smell inparticular. *Hymenium* spread all over except the trunk, up to 60 μ thick. *Basidia* clavate, $3 \cdot 5$–$4 \cdot 6\ \mu$ broad. Sterigmata 4, sometimes 2, straight or slightly incurved, $3 \cdot 5$–$7\ \mu$ long. *Basidiospores* broadly ellipsoid or ovoid, papillate, hyaline, smooth, aguttate, occasionally one guttule filling half of the spore cavity observed, $3 \cdot 5$–$4 \cdot 2 \times 3 \cdot 5\ \mu$. *Hyphæ* monomitic, hyaline, branched, thin-walled, parallel, mostly inflated, a few narrow hyphæ uninflated, septate, septa at short intervals, at longer intervals in narrow hyphæ, clamps absent, secondary septa absent, 2–12 μ broad, narrow ones $1 \cdot 7$–$3 \cdot 5\ \mu$ broad while inflated ones $5 \cdot 2$–$12\ \mu$ broad, hyphal cells 25–63 μ long (Pl. XVIII, Fig. 3; Text-Fig. 6, A–B).



TEXT-FIG. 6. *Clavaria vermicularis* Fr. var. *gracilis* Bourd. et Galz. A. Basidiospores, ×880. B. Basidia, ×880.

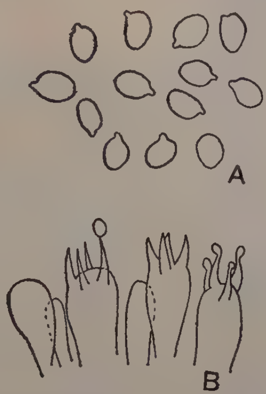
Collected on soil under Oak forest, Mussoorie, August, 1953, 59.

The var. *gracilis* Bourd. et Galz. is determined by solitary, gregarious, cæspitose (usually less cæspitose) fruit bodies with a distinct and characteristically transluscent or transparent to glassy trunk and broadly ellipsoid to ovoid small spores ($3 \cdot 5$–$4 \cdot 2 \times 3 \cdot 5\ \mu$).

28. *Clavaria vermicularis* Fr. f. *fasciata* Bourd. et Galz.

Fructifications gregarious, cæspitose, erect, slender, medium-sized, radial, trunk present, sparsely branched, rarely simple, firm-fleshy, smooth, glabrous, milk-white, up to 5 cm. tall, cæspitose clusters up to $1 \cdot 5$ cm. broad, individual clubs up to 4 mm. broad. Trunk indistinct, narrower than the club above, lighter coloured, cylindrical, about one-fourth of the total length of the clubs. Clubs cylindrical, grooved, sometimes fused together, simple but mostly branching only once near the top into unequal dichotomous branches, antler-like protuberances given out rarely, apices concolorous and blunt. Flesh concolorous. Taste and smell inparticular. *Hymenium* spread all over except the

trunk, up to $52\,\mu$ broad. *Basidia* clavate, $5{\cdot}3$–$7{\cdot}7\,\mu$ broad. Sterigmata 4, rarely 2, $3{\cdot}5$–$5{\cdot}3\,\mu$ long. *Basidiospores* pale yellowish, obovate, rarely globose or subglobose, papillate, smooth, aguttate, $5{\cdot}3$–$5{\cdot}6 \times 3{\cdot}2$–$3{\cdot}9\,\mu$. *Hyphæ* monomitic, hyaline, parallel, thin-walled, branched, mostly inflated, some hyphæ narrow and uninflated, septate, septa mostly at short intervals, at longer intervals in narrow hyphæ, clamps absent, secondary septa absent, $3{\cdot}5$–$21\,\mu$ broad, hyphal cells 18–133 μ long or even longer (Pl. XVIII, Fig. 4, Text-Fig. 7, A–B).



TEXT-FIG. 7. *Clavaria vermicularis* Fr. f. *fasciata* Bourd. et Galz. A. Basidiospores, ×880. B. Basidia, ×880.

Collected on soil under Oak forest, Chakrata Toll, Mussoorie, August, 16 1953, 60.

F. fasciata Bourd. et Galz. of *Clavaria vermicularis* Fr. is easily differentiated from the var. *gracilis* Bourd. et Galz. by its regularly cæspitose fructifications with indistinct trunk.

ACKNOWLEDGEMENTS

The writers are deeply indebted to Mr. E. J. H. Corner, F.R.S., of the Botany School, Cambridge, England, for valuable criticism and help in the identification of some of the Clavarias and Prof. P. N. Mehra, Head of the Panjab University Botany Department, for providing facilities and encouragement. They are also thankful to Mr. B. Khanna for making illustrations of some of the fruit bodies.

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Explanation of Plate

Fig. 1. *Clavulina cristata* (Fr.) Schroet var. *curta* Jungh.

Fig. 2. *Clavaria fumosa* Fr.

Fig. 3. *Clavaria vermicularis* Fr. var. *gracilis* Bourd. et Galz.

Fig. 4. *Clavaria vermicularis* Fr. f. *fasciata* Bourd. et Galz.

S. Thind & G. P. S. Anand

STUDIES IN PTERIDACEÆ

II. *Hemionites* Linn.

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(Received for publication on January 4, 1956)

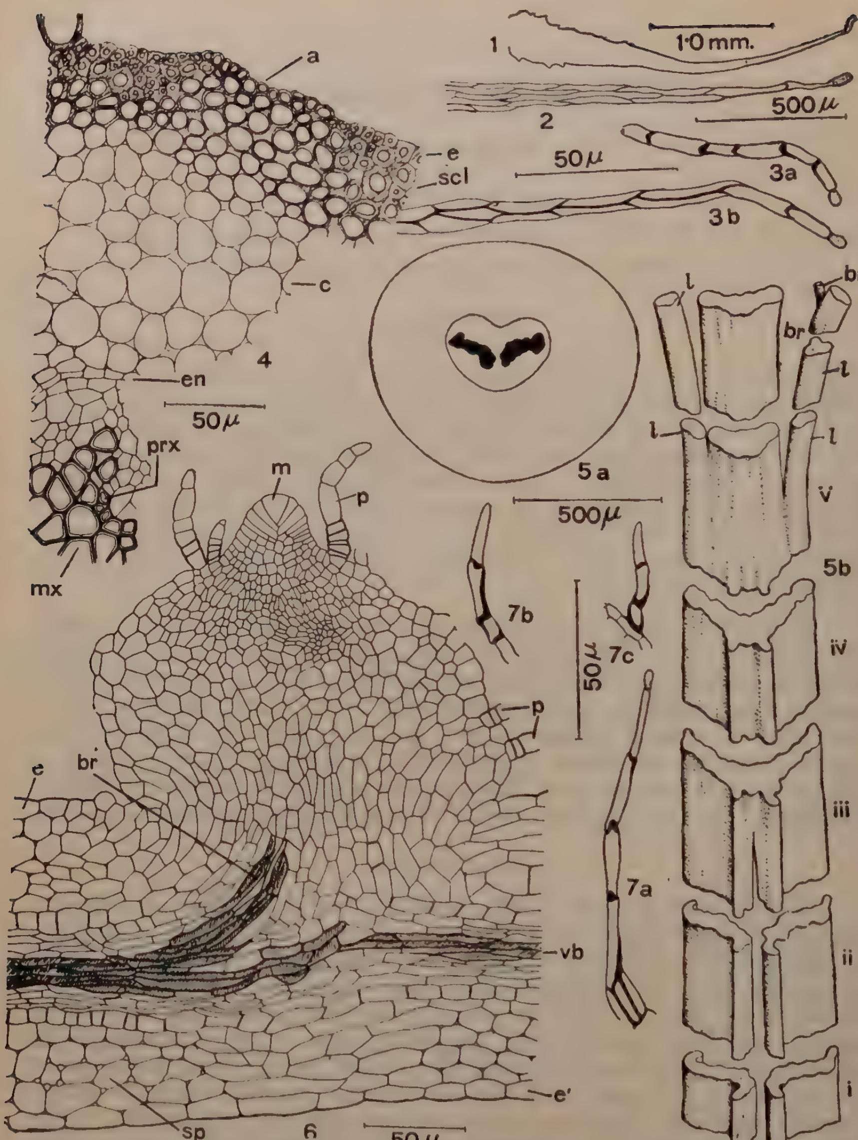
Introduction

Hemionites Linn. is a small genus of ca. 8 sps., mainly of tropical America, *H. arifolia* being the only Oriental representative. The present study is based on the latter species. A small terrestrial fern of moderately dry localities occurring on the Malabar Coast of South India and plains of North-Eastern India (East Bengal, Assam and Burma), *H. arifolia* grows generally on exposed earth cuttings (loamy or gravelly soil) forming small rosettes of short-stalked, ovate-cordate, sterile leaves (and a few erect, long-stalked, cordate-hastate, fertile leaves during fertile seasons).

Methods of study followed are the same as reported earlier (Kachroo and Nayar, 1953; Nayar, 1954). Young sporophytes and all stages in development of gametophytes are studied entirely from sand cultures raised in earthernware pots supplied with Knop's solution from below and kept in shaded regions of the garden. Sporophyte morphology is based mainly on plants transplanted from natural surroundings to the gardens in Assam and later at the National Botanic Gardens, Lucknow. Morphology of exine is studied from acetolysed spores.

Observations

The rhizome is short, hard, obconical, erect, and covered by persistent leaf-bases, light-brown paleæ and long wiry roots. The palea is slightly clathrate, with a broad base and gradually tapering to an acuminate apex terminating in a glandular cell (Fig. 1) which is thin-walled, with thick brown contents and oblong in shape (Fig. 2). Multicellular uniseriate hairs with glandular tips occur intermixed with appendages intermediate between paleæ and hairs. The larger paleæ are ca. $4 \cdot 0 \times 0 \cdot 5$ mm., and generally have smooth margins except towards the base where sparse dentations are not uncommon. The fully grown regions of the rhizome are dictyostelic (with one to three leaf traces in a t.s.). All stages of transition from the protostelic to the dictyostelic condition are discernible in the earlier formed regions of the rhizome. The leaf trace is a single band curved with the concavity facing inwards. While passing through the cortex of the rhizome it becomes broadly V-shaped in t.s. The stele of the rhizome is exarch with the metaxylem composed of pitted tracheids. The xylem on the whole is very small in extent, being usually composed of one or two compact layers of tracheids only. The phloem is massive, surrounds



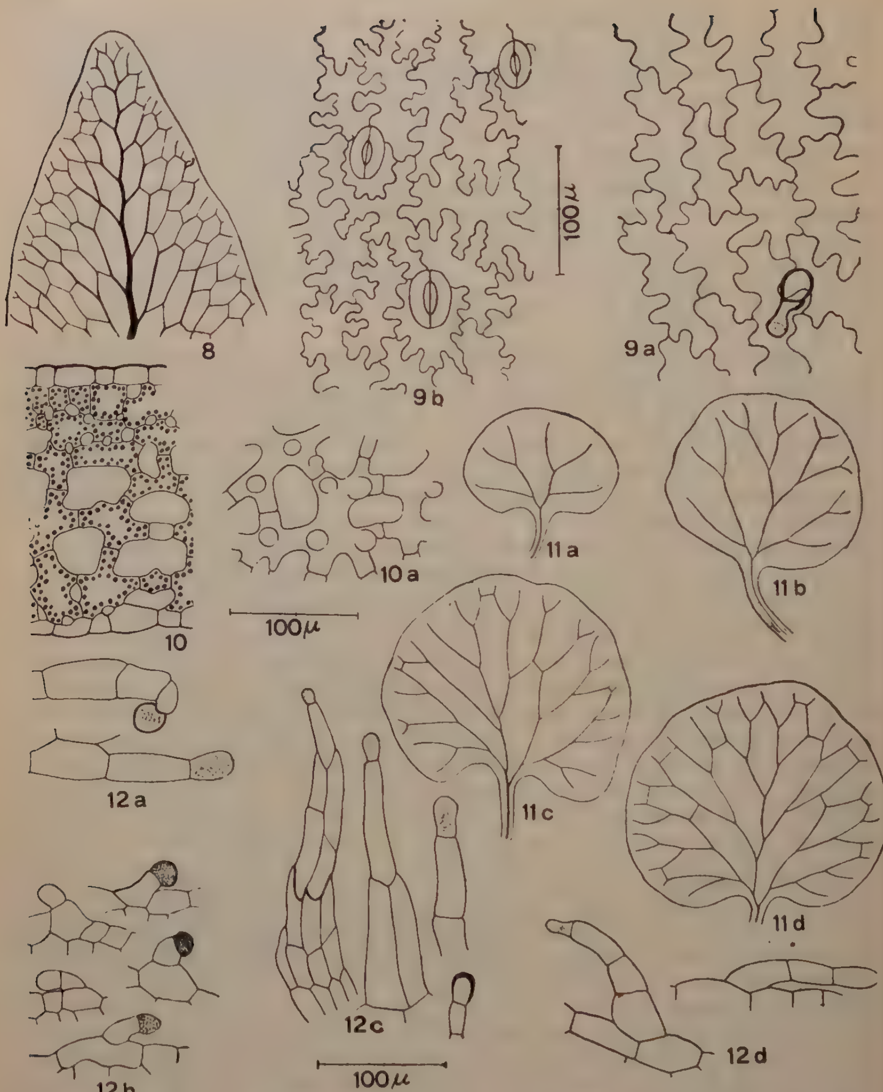
TEXT-FIGS. 1–7. Fig. 1. Palea from rhizome. Fig. 2. Tip of same in detail showing glandular apical cells. Fig. 3 (*a*). Hair from petiole. Fig. 3 (*b*). Paleæ from petiole. Fig. 4. T.s. of petiole (portion only) showing lateral aerating tissue; *a*, aerating tissue; *c*, parenchymatous inner cortex; *e*, epidermis; *en*, endodermis; *mx*, metaxylem; *prx*, protoxylem; *scl*, cortical sclerenchyma. Fig. 5 (*a*). T.s. of petiole base showing configuration of xylem band. Fig. 5 (*b*). Configuration of the xylem band in petiole of sterile sub-hastate leaf from region of attachment to rhizome to base of lamina showing origin of first pair of lateral veins and branch to foliar bud (Reconstructed from serial transverse sections); *l*, lateral vein. Fig. 6. T.s. portion of lamina base showing foliar bud in l.s.; *br*, vascular strand supplying bud; *e*, upper epidermis of leaf; *e'*, lower epidermis; *m*, apical meristematic cell of bud; *p*, paleæ; *sp*, spongy parenchyma; *vb*, vascular bundle of leaf (first lateral vein). Fig. 7 (*a*). Glandular foliar hair. Figs. 7 (*b*), (*c*). Non-glandular foliar hairs.

the xylem and is composed of thin-walled cells with large lumen, mixed with small parenchyma cells. Endodermis is continuous and thin-walled, the cells being smaller than the adjoining cortical cells. The latter as well as the pith cells have faintly thickened dark-brown walls and dark contents with included starch grains. Epidermis is thin-walled and irregular.

Roots are profuse, highly branched, dark-brown, with persistent root hairs and a diarch strap-shaped xylem core with phloem masses on either flat surface. The endodermis is thin-walled and the cortex is uniform, consisting of radially arranged parenchymatous cells with slightly darkish thin walls and not demarcated into two regions as is usual in higher ferns.

Leaves are borne spirally on the rhizome and are non-articulated. The petiole is dark-brown, shining, bearing paleæ shading off into hairs (Fig. 3, *a & b*) and with a median longitudinal groove on the adaxial surface. The epidermal- and 3 to 4 layers of hypodermal,- cells are sclerenchymatous except on the lateral sides of the petiole where they are thin-walled and with prominent intercellular air spaces, constituting the aerating system (Fig. 4). Towards the centre is the single vascular bundle, which at the base of the petiole has two separate xylem bands oriented at an angle to each other, with their abaxial margins converging (Figs. 5 *a*, 5 *b–i*) and each with two protoxylem regions, one at either margin. The protoxylem at the lower (abaxial) margins of the two bands curve away from each other. During their course up the petiole, the abaxial margins of the xylem bands gradually approach each other (Fig. 5 *b–ii*). Half way up the petiole the two bands meet and fuse at the metaxylem regions lying next to the protoxylem on the abaxial surface (Fig. 5 *b–iii*). The confluent band thus formed is "X"-shaped in t.s., with the downward (abaxial) arms of the "X" much smaller than the adaxials (Fig. 5 *b-iv*). Vascular connections to the lateral veins are given off marginally. Generally the first pair of lateral branches originates towards the distal end of the petiole (Fig. 5 *b–v*) and are the strongest, appearing in some leaves (especially the fertile ones) as prominent as the midrib itself and behaving in the same manner in giving off lateral secondary branches. Where this condition occurs the leaf lamina tends to be sub-hastate with the main lateral vein on either side forming a midrib to the basal auricles. (More commonly the lamina is ovate-cordate and the main lateral veins are not distinct.) One of these basal lateral veins (usually the first formed one) soon after entering the lamina gives off a branch which turns towards the upper epidermis and enters a vegetative bud (Fig. 5 *b–vi*, *br*; Fig. 6). The bud remains dormant and appears to be seated on the midrib towards its base though by origin it is lateral. The first leaf formed by the vegetative bud is on the side of the bud facing the midrib of the parent leaf. Under optimum conditions leaf buds with 3 to 4 developed leaves may be seen attached to the parent leaf. The buds are separated by decay of the latter and start off as new plants.

The lamina is simple, coriaceous and with the under-surface covered by hairs. The hairs are multicellular, uniseriate, either ending

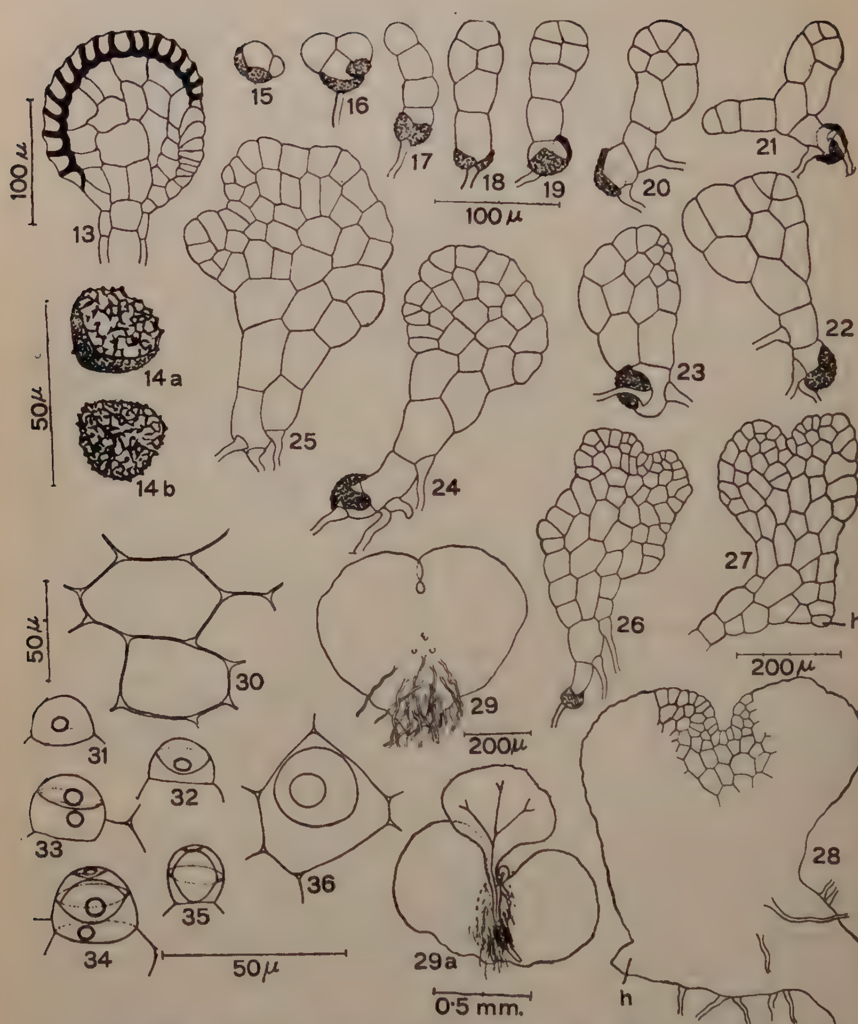


TEXT-FIGS. 8–12. Fig. 8. Tip of adult leaf showing venation. Fig. 9 (*a*). Surface view of upper epidermis. Fig. 9 (*b*). Same of lower epidermis. Fig. 10. T.s. of portion of sterile leaf. Fig. 10 (*a*). Mesophyll cells in surface view. Figs. 11 (*a*)–11 (*d*). Successive stages in the progression of juvenile leaves. Fig. 12 (*a*), Trichomes on petiole of first juvenile leaf. Fig. 12 (*b*). Same on lamina. Fig. 12 (*c*). Trichomes on petiole of third and fourth leaves. Fig. 12 (*d*). Same on lamina.

in glands like those on the petiole and rhizome (Fig. 7 *a*) or smaller with a terminal non-glandular acicular cell (Figs. 7 *b*, 7 *c*). Some of the larger hairs have broad bases. All hairs are brownish with the transverse septæ thickened. Margin of the leaf is entire and slightly curved on the lower surface. Venation is reticulate with a prominent midrib bearing inconspicuous (except the basal pair in cordate-hastate leaves already mentioned) lateral veins on either side alternately. Each lateral vein soon after origin forks unequally into a stronger anterior branch proceeding obliquely across the lamina and a weaker posterior one proceeding perpendicular to it. The former forms a branch on the anterior side which proceeding parallel to the midrib, fuses with the first posterior branch of the main lateral vein next in succession, forming a confluent vein which runs parallel to the main lateral veins, equidistant from them. This vein and the main lateral veins fork and fuse at regular intervals, forming obliquely placed polygonal aereolæ, which are smaller towards the margin of the lamina than near the midrib (Fig. 8). The reticulations are regular with closed meshes and the size of aereolæ decreases gradually towards the margin. The extreme tips of the veinlets end blindly just below the margin, there being no intramarginal commissure. The midrib dichotomises into two equal branches at the extreme tip of the lamina. Epidermis of the lamina is thin-walled and in surface view the cells have a zig-zag outline with sharp bends (Figs. 9 *a*, 9 *b*). Cells of the lower epidermis are narrower and more irregular compared to the upper. Chloroplasts are present in the cells of the lower epidermis but not of the upper. Stomata are restricted to lower epidermis on adult leaves while on juvenile ones they occur sparsely on the upper also. Each stoma is oval with the posterior half engulfed by an epidermal cell while the anterior is dovetailed into the corners of two to three cells. The mesophyll is undifferentiated and is composed of prominently armed chlorophyllous parenchyma (Figs. 10, 10 *a*), the hyopodermal layers on the upper surface being more compact than other mesophyll cells.

The first juvenile leaf of the sporophyte is spatulate to reniform (with a smooth margin) and supplied by a single vein dichotomising equally once or twice (Fig. 11 *a*). The next leaf has the medianly placed branch of the second dichotomy more prominent and dividing 2 or 3 times more than the other branches (Fig. 11 *b*). Generally the fourth leaf develops a cordate base and aereolæ but no definite midrib (Fig. 11 *c*). The first semblance of the midrib is found usually in the seventh leaf in which the lamina is broader than long (Fig. 11 *d*). The petiole and lamina of the juvenile leaves bear uniseriate multicellular glandular hairs (Figs. 12 *a*–12 *d*). Flattening of the lower regions of these to form paleæ occur generally on the lower regions of the petiole of the third or fourth leaf onwards. Vegetative buds are not found on juvenile leaves.

Fertile leaves are produced seasonally on mature plants. They are erect, with petiole 3 to 4 times longer than those of sterile ones and lamina hastate with three main diverging veins at the base. Vegetative buds are absent. Sporangia are distributed all over the lower



TEXT-FIGS. 13–36. Fig. 13. Sporangium. Figs. 14 (*a*), (*b*). Spores. Figs. 15–28. Stages in the development of prothallus. Fig. 29. Young cordate prothallus four months old. Fig. 29 (*a*). Mature prothallus with attached sporophyte. Fig. 30. Wing cells of mature prothallus showing collenchymatous thickenings. Figs. 31–35. Stages in development of antheridium (optical sections) Fig. 26. Mature antheridium in surface view showing intact opercular cell.

surface of the lateral veins and form reticulate patterns following the venation. The extreme margin of the lamina (with free ending veinlets) is free of sporangia and shows a slight tendency to fold downwards. Young fertile leaves have lamina rolled on the nether surface while the lamina of sterile ones is folded on the upper surface inwards (conduplicate). Lamina is recurved on the petiole in both. Hairs characteristic of the sterile leaves occur profusely over the surface, even between sporangia, on fertile leaves.

The sporangia (Fig. 13) are of the usual leptosporangiate type, though with a tendency to have a pear-shaped head as in *Cheilanthes*. The annulus is 16 to 18 cells long, continuous with a 6 to 8-celled stomium which does not extend up to the stalk and is separated from it by 1 to 3 thin-walled cells. Wall of the sporangium is composed of a large number of small cells as in *Cheilanthes*, etc., and the stalk is three cell thick at the top. Rarely the annulus is interrupted by thin-walled cells. The spores (Figs. 14 *a*, 14 *b*) are tetrahedral, 50 to 60 μ in diameter, dark-brown, devoid of episporium and with an indistinct triradiate mark. The exine bears prominent, dark-brown, ridge-like, irregular thickenings which protrude out giving a semblance of incomplete reticulations. Spore germination occurs within a week in culture. The intine protrudes out as a germ papilla at the region of the triradiate mark where the exine has ruptured. The germ papilla is densely chlorophyllous and is accompanied by a rhizoid (Fig. 15). In liquid media formation of a rhizoid may sometimes be delayed. Rhizoids are colourless and have a slightly swollen base. The germ papilla elongates and forms a 3- to 5-celled germ filament with short barrel-shaped cells (Fig. 17). The exine remains attached to the base of the filament as three more or less triangular pieces or in some cases may be shed off. The germ filament branches occasionally by the apical dome-shaped cell undergoing a longitudinal division followed by the two daughter cells continuing as separate filaments (Figs. 16, 21). Under healthy conditions flattening is initiated at the 4-celled stage of the filament (Figs. 18, 19), by the intercalary cells of the filament dividing longitudinally. All cells including the basal one, take part in the flattening under optimum conditions of growth. Finally the apical dome-shaped cell divides longitudinally producing two wedge-shaped daughter cells, both of which undergo further divisions resulting in a spatulate prothallus (Figs. 20, 22). The diffused meristematic activity of the apex later becomes restricted to one side of the gametophye (Fig. 23) where finally a two-celled lateral meristem is established (Fig. 24) which proceeds to form a cordate prothallus (Fig. 25). A hump, the size of which depends on the extent of activity of the original diffused meristem, is found invariably at the base of the cordate prothalli opposite to the point where the marginal meristem originated (Figs. 25, 27, 28-*h*). Rarely gametophytes growing under crowded, unhealthy conditions develop a single meristematic cell laterally rather than a group as usual (Figs. 26, 27). In such cases the growth of the gametophyte simulates the conventional type with an obconical apical cell, but the tell-tale hump towards the base betrays its lateral origin. Later in development this single cell ceases to function and a meristem

is formed by nearby daughter cells. About 4 months after germination a well-formed cordate thallus devoid of a midrib is established, under cultural conditions. Rhizoids are marginal in early stages of development of the prothallus but later become restricted to the middle regions. The mature gametophyte (Fig. 29) is cordate, broader than long and with the margins of the wings curved upwards. The midrib is prominent, 8 to 10 cells thick, and bears rhizoids intermixed with sex organs on the nether surface. Trichomes of all sorts are absent. The cells of the wings are thin-walled and have collenchymatous thickenings at the corners (Fig. 30). Chloroplasts are ovoid to globular and line the peripheral walls.

Vigorously growing, five months old, gametophytes produce antheridia before the formation of a midrib. Antheridia are restricted to the central region of the gametophyte on the ventral surface. They are globular and follow the general pattern of development for " Polypodiaceæ "[(Davie, 1951) Figs. 30–35]. Each has a basal saucer- or cup-shaped cell, a short annular cell, a more or less disc-shaped opercular cell and a central cell. The opercular cell is single (Fig. 36) and opens like a lid to release the sperms. Archegonia, which are of the usual type in higher ferns, are formed after antheridia (though both occur mixed in earlier stages) and initiate midrib formation.

Discussion

Diels (1902) includes *Hemionites* Linn. under the Gymnogrammineæ of Pterideæ (Family Polypodiaceæ), quite distinct from *Cheilanthes* and allies. Bower (1928) considers it a member of the central group of his Gymnogrammoid ferns, which as a group according to him might have evolved from forms like *Plagiogyria* Mett. (Plagiogyriaceæ Bower), *Todea* Wild. (Osmundaceæ R. Br.), *Mohria* Sw. (Schizæaceæ Mart.) and *Anemia* Swartz (Schizæaceæ). It is considered to be more advanced than *Onychium* Kaulf. and *Pityrogramma* Link., but more primitive than *Cheilanthes* Swartz or *Adiantum* Linn.

Christensen (1938) includes *Hemionites* under his Gymnogrammeæ (Lepidopterids) of Subfamily Gymnogrammeoideæ along with *Coniogramme* Fee, *Pityrogramma*, etc., quite distinct from *Cheilanthes*, *Adiantum* and *Onychium*. Ching (1940) includes *Hemionites* in his Tribe Gymnopterideæ of Family Gymnogrammaceæ Ching, showing affinities to Sinopteridaceæ Koidzumi and Pteridaceæ Ching. Copeland (1947) regards the genus as a Cheilanthoid of his complex family Pteridaceæ Gaudichaud. According to him *H. arifolia* (Burm.) Moore shows striking resemblance to *Syngramma* J. Sm., a Lindsæoid derivative. Holttum (1947, 1949) follows Bower in his conception of the Gymnogrammoid ferns, including *Hemionites*, considering them under his Adiantaceæ.

Hemionites agrees with most other Gymnogrammoids in being a fern of dry and arid localities, in having paleæ shading into hairs and attached by a broad base and in having a short solenostelic rhizome. The paleæ differ from those of Cheilanthoids, *Adiantum*, etc., in having

a terminal gland. *Actinopteris* Link. shows the closest resemblance in characters of paleæ to *H. arifolia*. The xylem band of the leaf trace bundle originating as a V-shaped strand with protoxylem on the curved adaxial surface and splitting into two curved strands which later fuse together by the metaxylem regions bringing the protoxylem on the abaxial surface of the bundle is characteristic of *H. arifolia*, *Cheilanthes*, *Aleuritopteris*, etc. This tendency of the xylem band to form the X-shaped bundle of the petiole is absent in *Adiantum*, *Actinopteris*, *Onychium*, *Pityrogramma*, etc. In those species of the former where two separate traces fuse they do so by the abaxial margins so that the protoxylem regions meet together first and continue to be on the adaxial side. In the latter genera the leaf trace is single from the beginning and is broadly U-shaped (in t.s.) with the protoxylem on the adaxial surface. Even in cases where due to expansion up the petiole the xylem band disintegrates as in *Onychium*, etc., the splitting on the abaxial side is irregular and reunions are always effected by fusions of the nearby margins as in *Pteris* and allies. The peculiar shape of the xylem band of the leaf bundle in *Hemionites arifolia* finds its parallel in *Lygodium* (Schizæaceæ). In both cases there are four protoxylem points and the metaxylem is mesarch. In *Plagiogyria* with which Bower suggests relationship the leaf bundle is broadly V-shaped. The venation of the lamina too can be traced back to *Lygodium* and Schizæaceæ. [Some species of *Lygodium* and *Anemia*—like *A. Phyllitidis* (L.) Swartz—possess reticulate venation closely resembling that of *H. arifolia*.] Presence of vegetative buds at the base of the lamina is a unique feature, not found in other Gymnogrammoids. Both *Anemia* and *Adiantum* form foliar buds replacing the terminal pinnule, *i.e.*, terminating the main vascular strand of the leaf. The bud in *Hemionites arifolia* cannot be compared with these because of its lateral position at the base of one of the main lateral veins of the lamina. A closer resemblance may be found with leaf buds of *Ampelopteris elegans* Kunze (in which buds occur in the axils of some of the pinnules, attached to their bases). The simple leaf form in *H. arifolia* might have evlolved from a pinnate leaved ancestor by reduction in which all except the terminal pinnule were reduced. But in those leaves with three basal nerves the first pair of prominent lateral veins represent a pair of pinnules confluent with the terminal one and the vegetative bud at the base of one of them thus occupies the position identical to that of *Ampelopteris*. Fertile leaves are in all cases three-nerved but do not bear vegetative buds. In some species of *Plagiogyria* like *P. pycnophylla* Kunze in which stolons are present the leaf sometimes fuses with the stolon to some extent (*see* Bower, 1928: Fig. 545). Such a fusion of a stolon with the leaf could have explained the position of the vegetative bud in *H. arifolia* but for the anatomy where the vascular supply to the bud distinctly originates form one of the lateral veins.

First juvenile leaves in *Pityrogramma* and *Onychium* are palmatisect with the main vascular bundle dichotomising to supply one veinlet to each lobe. In *H. arifolia* as in *Aleuritopteris* the cotyledonary leaf is simple with radially dichotomising veins. A midrib is evolved as in *Onychium*, *Pityrogramma*, *Lygodium*, etc., by the median branch

of the initial dichotomy becoming more prominent. Even in the leaves of the adult plant the dichotomising pattern is kept up in spite of the reticulations. The glandular trichomes found on the juvenile leaves especially those on the cotyledonary leaf are similar to those on the leaves of *Aleuritopteris* and *Pityrogramma*. In *Hemionites* the hairs gradually become elaborated into paleæ with glandular tips while in others the glandular hairs remain as such secreting a waxy substance, even on adult leaves, the paleæ being elaborations of non-glandular hairs.

Sporangia originate marginally in Schizæaceæ but in some of the genera like *Lygodium*, they may become pushed towards the superficial surface. But in all cases they terminate the fertile vein. In *Hemionites* on the other hand the extreme tips of veinlets (near the leaf margin) are sterile, sporangia being found on the surface of veins in other regions only. This along with the extreme low number of sporangia per " sorus " in Schizæaceæ presents a difficulty in deriving *Hemionites* from them. On the other hand the sporangia are superficial on veins and compare favourably with *Hemionites* in *Plagiogyria*. The annulus is not continuous with the stalk which is three cell thick at the top in *Hemionites* as in Cheilanthoids. *Actinopteris*, etc. But the sporangial head is not pyriform and composed of a very large number of cells as in the former. Development of the prothallus with a tendency to formation of a marginal meristem without the intervening apical cell stage is found in *Actinopteris*.

Hemionites thus appears to be better considered as distinct from Cheilanthoids, *Onychium*, *Pityrogramma*, *Adiantum* and *Actinopteris*, though showing resemblances to them in some character or other, the closest being to Cheilanthoids.

Summary

Hemionites arifolia (Burm.) Moore is a small fern of moderately dry localities with erect, hard, solenostelic rhizome covered by leaf bases, roots and paleæ. Paleæ shade off into hairs and have glandular tips. Petiole and lamina bear hairs and simple paleæ of the type on the rhizome. Leaf traces at their origin are simple gutter-shaped strands with an intact band of xylem which on entering the leaf base splits into two curved bands facing away from each other and each having two protoxylem strands one at either margin. Passing up the petiole the xylem bands fuse by the metaxylem regions above the abaxial margins, resulting in a characteristic X-shaped (in t.s.) bundle which on entering the lamina gives off lateral veins marginally. The first formed lateral veins on some of the sterile leaves are prominent and soon after entering the lamina one of these may bear a vegetative bud on the adaxial surface. The venation is reticulate, without included veinlets, and with free vein endings near the margin. Juvenile leaves are simple with dichotomising veins and the trasition to adult form entails only increase in size and establishment of a reticulate venation with a midrib. Fertile leaves are slightly different from sterile ones and the sporangia are spread over the veins on the abaxial surface

of the lamina occuring mixed with foliar trichomes. The annulus and stomium are separated from the stalk by unthickened wall cells of the sporangium. The stalk is three cell thick at the top and the sporangial wall is of large number of small cells. Spores are dark brown, tetrahedral and with irregular ridge-like protrusions on the exine. On germination a germ filament consisting of 3 to 5 short cells is formed which soon flattens by longitudinal divisions of all cells including the basal and terminal ones, resulting in a spatulate prothallus where a marginal lateral meristem is soon developed. An apical cell with two cutting faces is not developed but under unhealthy conditions the marginal meristem may be represented by a single cell. In all cases a hump is developed towards the base opposite to the point where the lateral meristem is developed. Mature prothalli are cordate, devoid of trichomes, having a well-developed midrib and developing sex organs on the nether surface.

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MORPHOLOGY OF THE PACHYTENE CHROMOSOMES AND MEIOSIS IN *SORGHUM SUBGLABRESCENS*, A EU-SORGHUM

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Introduction

Our present knowledge of the morphology of the pachytene chromosomes in the genus *Sorghum* reveals that the pachytene chromosomes in Eu-Sorghums, which include the economically important grain Sorghums, are characterized by differential stainability and distinct centromeres, while in the rest of the Sorghums they are uniformly stained with acetocarmine with no marked accumulation of stain in any one region of the chromosome (Garber, 1947, 1950). In 1937, Longley and later Garber (1950) made some observations on the pachytene chromosomes of *Sorghum vulgare*, a Eu-Sorghum. In this, the regions immediately adjacent to the distinct centromeres were found to be heavily stained and the quality of staining decreased noticeably beyond these regions until the remainder of the chromosome was almost unstained especially at the end of each arm. More recently, Harpstead, Ross and Franzke (1954) studied the pachytene stage in *S. vulgare* during the course of their investigations on colchicine-induced variants in *Sorghum*. The photomicrographs of nuclei at the pachytene stage stained in propionocarmine presented in their paper clearly show the heavily stained proximal and the lightly stained distal regions of the chromosomes. The above authors, however, made no reference to these features in the text, their object of study of this stage being only to determine if any gross chromatin rearrangement was responsible for the origin of variant plants obtained by colchicine treatment.

So far no complete account of the morphology of pachytene chromosomes of the entire complement in any Eu-Sorghum is available. As the Eu-Sorghums form an economically important crop in the agriculture of many countries a detailed cytological study of several species belonging to them has been undertaken in this department for such a knowledge will considerably aid cytogenetical studies and will lead to a fuller understanding of the genetics of the grain Sorghums. During the course of these studies we found that *Sorghum subglabrescens* Schw. et Asch., to be very suitable for a study of the morphology of the pachytene chromosomes and it was possible to analyse the entire complement enabling the identification of all the chromosomes in each of ten nuclei analysed. The pachytene chromosomes in this species could be exceptionally well spread out using the acetocarmine squash technique

and they could be followed from one end to the other as done earlier in a few plants like *Zea mays* (McClintock, 1931; Longley, 1938, 1941; Rhoades, 1950), *Secale cereale* (Lima-de-Faria, 1950, 1952), *Lycopersicum esculentum* variety Sutton's Best of all (Brown, 1949; Barton, 1950), and *Plantago ovata* (Hyde, 1953).

Results obtained in the present study on the morphology of the pachytene chromosomes and other meiotic stages in *Sorghum subglabrescens* are presented in this paper. Some observations made on the pachytene chromosomes and meiosis in *S. roxburghii* Stapf, another Eu-Sorghum, are also included here for comparison.

Materials and Methods

Seeds of *Sorghum subglabrescens* were obtained from the Agriculture Research Station, Nandyal, Andhra State, and cultures were raised in the Andhra University Botanical Gardens at Waltair.

For the study of pachytene chromosomes the modified acetocarmine technique developed by Lima-de-Faria (1948) for rye, was found very suitable. The young inflorescences were fixed in 1:4 acetic alcohol for 12–24 hours and then transferred to 95% alcohol overnight, after which the material was stored in 70% alcohol in a refrigerator until used for study. The preparations made according to this method showed a clear definition of the differentially stained parts of the pachytene chromosomes in almost unstained cytoplasm. The technique of iron alum mordanting prior to staining with acetocarmine originally developed for staining tomato chromosomes by Dr. Marta S. Walters, and later successfully employed by Brown (1949) and Barton (1950) was also tried but did not prove suitable as the cytoplasm was darkly stained obscuring details of the pachytene chromosomes.

All photomicrographs presented in this paper were taken from preparations when they were still fresh using a Leica camera with an attachment for photomicrographic work.

Measurements of lengths of entire chromosomes and of the heavily and lightly stained parts were made from camera lucida drawings of the pachytene chromosomes from completely analysable nuclei with the aid of a map measurer.

Pachytene Chromosomes

The ten chromosomes of *Sorghum subglabrescens* at the pachytene stage are characterized by (*i*) distinct and well-defined centromeres, (*ii*) deeply staining segments of varying length in each arm adjacent to the centromere followed by (*iii*) lightly staining distal regions of different lengths (Text-Fig. 1 and Plate XIX, Figs. 1–3). The above characteristics are considered below in detail.

The centromeres are oval-shaped and seem to resemble somewhat in their structure those described in rye by Lima-de-Faria (1949). The structure of the centromere could not be made out clearly in

Sorghum subglabrescens, but in a few favourably stained preparations of *S. roxburghii* there seem to be present a pair of lightly stained chromomeres in its centromere. More intensive study, using fixatives other than those involving acetic acid which Lima-de-Faria (1950) found not suitable for study of centromere structure, is needed before definite conclusions can be reached.

The heavily stained regions of the chromosomes consist of chromomeres which stain deeply and the lightly stained distal regions show very feebly staining chromomeres, which are difficult to differentiate from the cytoplasm in which they were spread out in the squash preparations. The transition between the proximal deeply staining and the distal lightly staining segments in each arm is rather abrupt except in the case of two chromosomes of the complement in which the region of transition consists of 3 or 4 chromomeres capable of being stained noticeably and were arranged in a characteristically seriated manner. This feature proved particularly useful in individually recognising the two chromosomes from the rest of the complement. In another chromosome of the complement almost the entire short arm is constituted by the deeply stained segment. In *S. roxburghii* which has also been examined for comparison, the structure of the differentially stained chromosomes is essentially similar except that in it the deeply stained segments are more pronounced (Plate XIX, Figs. 2 and 3).

There are no knobs and no pronounced chromomeres at the ends of the chromosomes. The longest chromosome (ch. 1) of the complement is the nucleolus organising chromosome, the nucleolus organizing body being situated very near to the centromere in the short arm.

Pachytene Pairing

Pre-pachytene stages proved difficult to study. However, in a number of nuclei it was clearly observed that the pairing was regularly initiated in the deeply staining segments and the parts immediately adjacent to them. At this stage the pairing was not evident in the lightly stained regions. At a later stage the pairing becomes complete all along the length of the chromosomes. In late pachytene and early diplotene, the split threads fall apart earlier in the zones corresponding to the deeply staining and adjacent regions. Frequently the centromeres were found still attached to each other with a loop on either side of it.

The pairing properties of the pachytene bivalents observed in the present study show a striking similarity to the pairing behaviour of the differentially condensed pachytene chromosomes of *Agapanthus* (Darlington, 1933), in which the proximal parts are in advance....the distal parts in the process of condensation which has been ascribed to earlier assumption of spiral in the condensed parts. In *Agapanthus* (Darlington, 1933) also, as in *S. subglabrescens*, corresponding to the early synapsis of the over-condensed parts there is an earlier appearance of the secondary split in the same region accompanied by earlier falling apart of the chromosomes.

Mitotic stages from the root tip cells of *S. subglabrescens* particularly at prophase showed the middle deeply stained regions followed by lightly stained regions towards the chromosome ends. In this respect, *S. subglabrescens* resembles tomato (Brown, 1949) and *Plantago ovata* (Hyde, 1953) in which also the mitotic chromosomes show differentially stained segments. Earlier, Darlington (1933) made some observations on the mitotic chromosomes in the pollen grain division in *Agapanthus* which, however, did not show any differential regions in them, although the meiotic chromosomes are differentiated into deeply stained and lightly stained regions.

Frequent non-homologous association of the centromeres takes place during the meiotic prophase. Association of two non-homologous centromeres is common while that of three is not infrequent in both the species investigated. Plate XIX, Fig. 3, shows a case of non-homologous association of centromeres observed in *S. roxburghii.* Similar observations have been made in *Agapanthus* (Darlington, 1933) and in tomato by Brown (1949). Darlington (1933) considered the cases of non-homologous association of centromeres in *Agapanthus* as due to interlocking of the non-persistent kind. In the light of the accepted concept relating to the common forms and functions of the centromeres, it appears to us that they exert an attraction leading to fusion in a certain sense more favourably in differentially condensed chromosomes in which a lapse of repulsion exists between the deeply stained segments consequent upon the lower surface charge they are supposed to carry (Darlington, 1937, pp. 315 and 498).

Diagnostic Features of Pachytene Chromosome Complement

Based upon the average values of lengths obtained by complete analyses of chromosomes in ten entire nuclei, the ten pachytene chromosomes of *S. subglabrescens* have been designated in the order of their decreasing length as chromosome one to chromosome ten, chromosome one being the longest and chromosome ten being the shortest in the complement following the method of numbering originally adopted by McClintock (1929) in *Zea mays* and later by Barton (1950) in tomato. Table I shows the measurements based on the analyses of all the pachytene chromosomes in each of ten entire nuclei.

The following is a description of the individual pachytene chromosomes of the complement giving their chief diagnostic morphological features which proved particularly useful in identifying them individually.

Chromosome 1.—This is the longest of the complement, measuring on an average 80·38 microns, and has an attachment to the nucleolus very near to the centromere in the short arm. The nucleolar organising region is spherical in shape and distinctly greater in diameter than the adjoining deeply stained segments. Another characteristic feature of this chromosome is the presence of a deep staining chromomere terminating the heavily stained region in the long arm.

TABLE I

Average values of lengths in microns of the pachytene complement obtained from the complete analysis of ten cells in S. subglabrescens

Chromosome	Long arm			Short arm			Total Chromosome‡	Arm ratio S.A./L.A.
	H.S.R.*	L.S.R.†	Total arm	H.S.R.	L.S.R.	Total arm		
1	3·75	40·60	45·07	2·71	32·02	35·31	80·38 (2·35)	0·78
2	4·88	36·06	41·69	3·77	19·39	23·69	65·38 (1·66)	0·57
3	4·07	30·71	35·50	3·61	21·51	25·65	61·15 (2·77)	0·724
4	4·81	25·14	30·19	6·21	15·68	22·89	53·08 (1·67)	0·758
5	4·21	21·69	26·82	5·91	13·04	19·53	46·35 (0·95)	0·73
6	5·77	28·93	35·33	5·31	1·10	6·90	42·23 (1·13)	0·195
7	3·77	21·80	26·20	3·61	11·82	15·92	42·12 (1·34)	0·61
8	4·78	16·51	21·64	3·43	16·08	19·94	41·58 (1·07)	0·92
9	4·90	16·74	22·27	4·62	10·83	15·96	38·23 (0·97)	0·72
10	4·42	13·11	18·10	3·17	11·04	14·67	32·77 (1·04)	0·81

* Heavily stained region.

† Lightly stained region.

‡ Standard errors for entire lengths of the chromosomes are given in parentheses.

Chromosome 2.—The chief feature which proved most useful in the identification of this chromosome is that the long arm is approximately twice the length of the short arm. The heavily stained parts in both arms show an abrupt transition to the lightly stained zones. The heavily stained region in the long arm is slightly greater than that in the short arm.

Chromosome 3.—This is difficult to distinguish from the succeeding chromosome particularly in nuclei where it cannot be followed from end to end, due to the fact that both of them come close to one another in length. In some of the cells analysed it is even lesser in length than chromosome 4 while in still others it is slightly more in length than chromosome 2. However, the presence of a deep staining chromomere terminating the heavily stained part in the short arm comparable in size to that seen in chromosome 1 makes its identification certain.

Chromosome 4.—The ready identification of this chromosome on the basis of length alone is difficult for the reasons already mentioned under chromosome 3. The deeply stained chromomere terminating the heavily stained segment in the long arm and the presence of a series

of four small chromomeres in the transition region of the short arm capable of being well stained together form a reliable diagnostic basis.

Chromosome 5.—This is marked by the presence of a series of three small chromomeres in the transition region in the short arm like that described under the preceding chromosome. This chromosome measures on an average 46·35 microns.

Chromosome 6.—This is the easiest chromosome to identify in the complement due to the marked asymmetry of its arms. The long arm is about five times the length of the short arm. Also the short arm is completely stained deeply but for a small terminal part of about 1·1 microns in length. The average length of the chromosome is 42·23 microns.

Chromosome 7.—This is chiefly distinguished from the rest of the long chromosomes by the comparative short length of the lightly stained segment in the short arm. The short arm measures about half the length of the long arm (arm ratio = 0·61).

Chromosome 8.—This is readily recognised from the rest of the complement by the nearly equal length of its arms. Although in this feature chromosome 10 comes very near to it, in none of the cells analysed it comes near to this chromosome in total length there being a difference of 8·8 microns on an average.

Chromosome 9.—The quick recognition of this chromosome among the short chromosomes of the complement is facilitated by the characteristic presence of two deeply stained chromomeres terminating the heavily stained region in either arm. Its arm ratio is 0·72.

Chromosome 10.—This is the shortest chromosome of the complement measuring 32·77 microns long on an average. The arm lengths in many of the nuclei analysed have been found to be approximately equal, although on an average a difference of more than three microns was found.

Basing on the quantitative data presented in Table I the diagram of the 10 chromosomes (Text-Fig. 2) has been constructed to bring about the diagnostic features of the individual chromosomes that have been considered particularly useful in tracing their identity in the complement.

Diakinesis and Metaphase I

The differentially stained regions can be followed through diplotene to the late diakinesis stage both in *S. subglabrescens* and *S. roxburghii*.

It was possible to observe chiasmata in early and late diakinesis, metaphase I and even in early diplotene stages. Altogether 45 nuclei could be analysed in *S. subglabrescens* and 75 in *S. roxburghii* (Table II). It is clear from the data given in Table II that there is a decrease in the number of chiasmata per nucleus from diplotene to metaphase I. This is further borne out by the values of terminalisation coefficient at metaphase I given in the last column of Table II for the two species.

TABLE II

Chiasma frequencies at late-diplotene to metaphase I stages in Sorghum subglabrescens *and* S. roxburghii

Stage	No. of cells analysed	Bivalents with				Total Xta	Average No. of Xta per nucleus	Average No. of Xta per bivalent	Terminalisation coefficient
		4Xta	3Xta	2Xta	1Xma				
			S. subglabrescens						
Late diplotene	3	7	14	8	1	87	29·0	2·9	0·15
Early diakinesis	14	..	54	83	3	331	23·64	2·36	0·22
Late diakinesis	12	..	..	116	4	236	19·66	1·97	0·45
Metaphase I	16	..	..	153	7	313	19·56	1·96	0·79
			S. roxburghii						
Late diplotene	3	2	17	11	..	81	27·0	2·70	0·12
Early diakinesis	9	1	26	62	1	207	23·0	2·30	0·20
Late diakinesis	16	..	..	153	7	313	19·56	1·96	0·57
Metaphase I	47	..	..	446	24	916	19·50	1·95	0·75

It can be seen from these values that the process of the terminalisation in both the species is incomplete. In this respect the two species of Eu-Sorghum studied resemble plants like *Agapanthus*, *Avena* and *Zea mays* (Darlington, 1933 *a*, 1933 *b* and 1934) and *Lycopersicum esculentum* (Brown, 1949).

From the analyses of the nuclei at diakinesis (Table III) it was found that of the total of 260 bivalents in *S. subglabrescens* and 250 in *S. roxburghii*, 253 in the former and 242 in the latter are of the ring type.

TABLE III

Frequency of rod and ring bivalents at diakinesis and metaphase I

Species	Stage	Ring bivalents		Rod bivalents		Total bivalents
		Number	Per cent.	Number	Per cent.	
S. subglabrescens	Diakinesis	253	97·3	7	2·7	260
	Metaphase I	153	95·6	7	4·4	160
S. roxburghii	Diakinesis	242	96·8	8	3·2	250
	Metaphase I	446	94·9	24	5·1	470

Thus, in more than 90% of the nuclei at least one chiasma in either arm of each chromosome of the complement is formed irrespective of any differences in them. On the assumption that there is no localisation and that chiasma formation is at random, there should be a proportion of the chiasma in the short arm of chromosome 6 which is almost entirely constituted by its deeply stained segment, the distal light staining region measuring $1 \cdot 10$ microns only while the total length of the short arm is $6 \cdot 90$ microns on an average. On the general assumption that the number of chiasmata formed is proportional to the length of the chromosome, $6 \cdot 90/35 \cdot 33 \times 2 \cdot 17 = 0 \cdot 42$ chiasma should be formed in the short arm of chromosome 6 and $1 \cdot 10/6 \cdot 9 \times 0 \cdot 42 = 0 \cdot 07$ should be located in the light staining distal region of the arm alone, the rest being formed in the proximal dark staining region. On these considerations it may be inferred that it is very likely that there is no localislation of chiasmata in *S. subglabrescens* such as present in tomato (Brown, 1949 and Barton, 1951) and *Plantago ovata* (Hyde, 1953). Since the general inferences made by us in this respect are not directly correlated with any observations on any one of the identified bivalents on the origin and behaviour of chiasmata, a more certain evidence such as those obtained by Brown (1949) with reference to the nucleolar chromosome and by Barton (1951) on the experimental basis in tomato is necessary before establishing this point of view. Until such direct evidence as in tomato is obtained with reference to *Sorghum* it is to be considered that chiasmata are formed at random all along the length of the chromosome in *Sorghum subglabrescens*.

Other meiotic stages of divisions I and II show normal features and at the end of the two divisions the microspore nuclei show ten chromosomes in each of them.

Discussion

The striking differential stainability of the pachytene chromosomes is a characteristic found in all the Eu-Sorghums so far investigated namely *Sorghum vulgare* (Longley, 1937 and Garber, 1950), *S. subglabrescens* and *S. roxburghii* (present report) and serves to distinguish them from the rest of the Sorghums studied (Garber, 1950).

As in the differentiated chromosomes of *Antirrhinum* (Ernst, 1938, 1939), tomato (Brown, 1949; Barton 1950) and *Plantago ovata* (Hyde, 1953) the pachytene chromosomes show proximal darkly staining segments followed by distal lightly staining ones in each arm. These differential regions can be followed until late diakinesis stage is reached in the meiotic cycle. In *S. subglabrescens* these regions can also be seen in mitotic chromosomes in the root tip cells. In *Plantago ovata*, Hyde (1953) was able to identify morphologically the chromosomes of mitotic prophase with those of pachytene. He concluded that this continuity suggests that the differentiation is inherent in each individual chromosome and is controlled by its submicroscopic structure.

In 1928, Heitz originally described the differentially stained regions in the chromosomes of some plants and designated the material in the

darkly staining regions as heterochromatin and that in the lightly staining regions as euchromatin. He also specifically suggested that heterochromatic segments are genetically inert and euchromatic active. Although in *Drosophila* this hypothesis with some modifications has been substantiated, in plants, however, it remains in doubt due to the fact that only a very few plants have yet been found with differentiated chromosomes in which critical cytogenetic work on the gene content of the heterochromatin is possible. So far, only in *Antirrhinum* and in tomato a detailed knowledge of the differentiated pachytene chromosomes made cytogenetic work possible. As detailed study of morphology of the pachytene chromosome complement leading to individual identification of the chromosomes has now become possible in *S. subglabrescens* and as it is possible to acquire similar knowledge in more Eu-Sorghums in the near future, it is hoped that Eu-Sorghums would prove to be very favourable material for critical cytogenetic work on the gene content of the material in the deeply staining regions which seem to be similar in certain respects to heterochromatin in plants.

Although the structure of the meiotic chromosomes of tomato resembles closely those regarded as differentiated into zones containing hetero and euchromatin, Brown (1949) used the terms 'chromatic' and 'achromatic' as the latter seem to shorten markedly without acquiring an appreciable capacity to stain deeply, unlike the typical euchromatin described by Heitz (1928) which acquires during prophase a marked capacity for deep staining and also because the various chromatic zones in tomato seemed to show a differential behaviour during the resting stage. In view of the fact that the lightly stained zones in *S. subglabrescens* do not acquire a marked capacity to stain deeply as they contract and that the differential parts show deviations from those described in tomato in their synaptic properties and in the formation of chiasmata, simple terms 'heavily stained or deeply stained' and 'lightly stained or feebly stained' have been used.

Pairing properties of the differentiated regions of the chromosomes vary in different organisms. In tomato, Brown (1949) found that pairing is initiated during late zygotene or early pachytene stages in the achromatic zones followed later by pairing in the chromatic zones. It was not possible for him to study the separation of the split sister chromosomes at the diplotene stage. In *Plantago ovata*, Hyde (1953) recorded that pairing is initiated regularly in the middle segments while separation of the divided sister chromosomes takes place, however, in the end segments during the early diplotene stage. Earlier, in his studies on the synapsis of the differentially condensed chromosomes in *Agapanthus* and *Fritillaria* Darlington (1933, 1935) showed that pairing initially takes place during pachytene in the condensed proximal regions followed by separation of the split chromosomes at diplotene in the same parts. In its pairing properties of the differentially stained regions, *S. subglabrescens* shows a close similarity to *Agapanthus* and *Fritillaria*. In *Fritillaria* the earlier pairing in proximal deeply staining regions is believed to be associated with localisation of chiasmata in the regions adjacent to the centromere. Consequently, an assumption of

a timing difference at meiosis in that the proximal parts are in advance to the distal parts with a possible relation of the former to the centromere satisfactorily explains the behaviour of heavily and lightly stained regions of the pachytene chromosomes of *S. subglabrescens.* In the Eu-Sorghums investigated during the present study, however, there does not seem to be any localisation of chiasmata as in *Fritillaria.*

It has been observed in several plants with differentiated chromosomes that the chiasmata are localised in the lightly stained regions. In 1933, Geitler found in *Agapanthus* the formation of as many as four chiasmata per bivalent, all in the euchromatic regions. Barton (1951) concluded, on the basis of experimental evidence, that chiasmata probably do not occur in the chromatic zones of tomato. More recently, Hyde (1953) made similar observations in *Plantago ovata* and concluded that chiasma formation does not take place in the deeply staining middle segments. As already pointed out in this paper, on the basis of observations on the distribution of chiasmata particularly with reference to the almost entirely deeply staining short arm of chromosome 6 in *S. subglabrescens*, there does not seem to be any apparent localisation of chiasmata in the lightly stained distal regions. Thus, in Eu-Sorghums the chromomeres of the deeply stained segments do not seem to be inherently different from those in the lightly stained regions in the capacity of the recombination of the genic material in them.

SUMMARY

S. subglabrescens Schw. et Asch., a Eu-Sorghum, is found an exceptionally favourable material for the study of pachytene chromosomes with special reference to their differential staining reaction. The differential segments can be clearly seen up to diakinesis stage in the meiotic cycle. The mitotic chromosomes in the root tip cells are also observed to show the differentially stained regions. A careful and critical study of the heavily stained proximal segments and the distal lightly stained regions, the relative lengths, arm ratios in the pachytene chromosomes proved very useful in identifying each of the ten chromosomes of the complement. Diagnostic features of each one of the pachytene chromosomes and diagram based on them are presented.

Studies on the pairing properties of the differentially stained parts show that synapsis takes place initially during early prophase in the heavily stained regions and is followed by the earlier separation of the split chromosomes in the same regions at diplotene. An assumption of timing difference at meiosis in that the proximal parts are in advance to the distal lightly stained parts is considered to be satisfactory to explain the observations as has been already done in other plants like *Agapanthus*.

Detailed studies on the distribution of chiasmata in *S. subglabrescens* and *S. roxburghii* show no apparent localisation of these in the lightly stained regions indicating thereby that the deeply and lightly stained regions show no differentiation of the chromomeres constituting them in their capacity to recombine.

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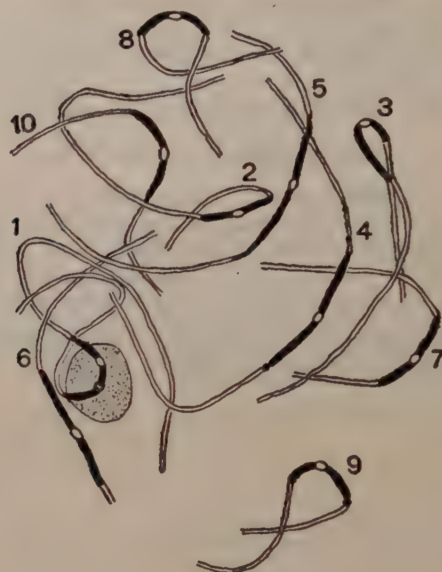
Explanation of Plate XIX

Fig. 1. Pachytene in *S. subglabrescens*, ×ca. 1,500.

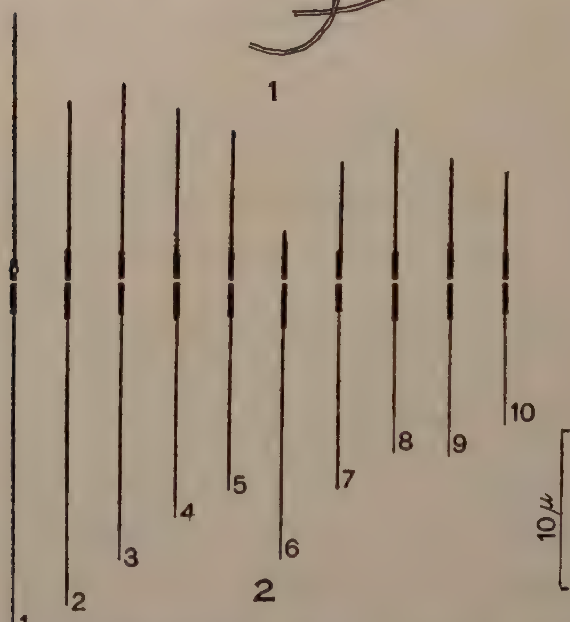
Fig. 2. Pachytene in *S. roxburghii*, showing the relatively more pronounced heavily stained regions adjacent to centromeres, ×ca. 1,500.

Fig. 3. Another cell at pachytene in *S. roxburghii*, showing a case of non-homologous association of centromeres, ×ca. 1,500.

Figs. 4–6. Early diakinesis, late diakinesis and metaphase I respectively in *S. subglabrescens*, showing the relative contraction of the differentially stained regions in the bivalents, ×ca. 1,000.

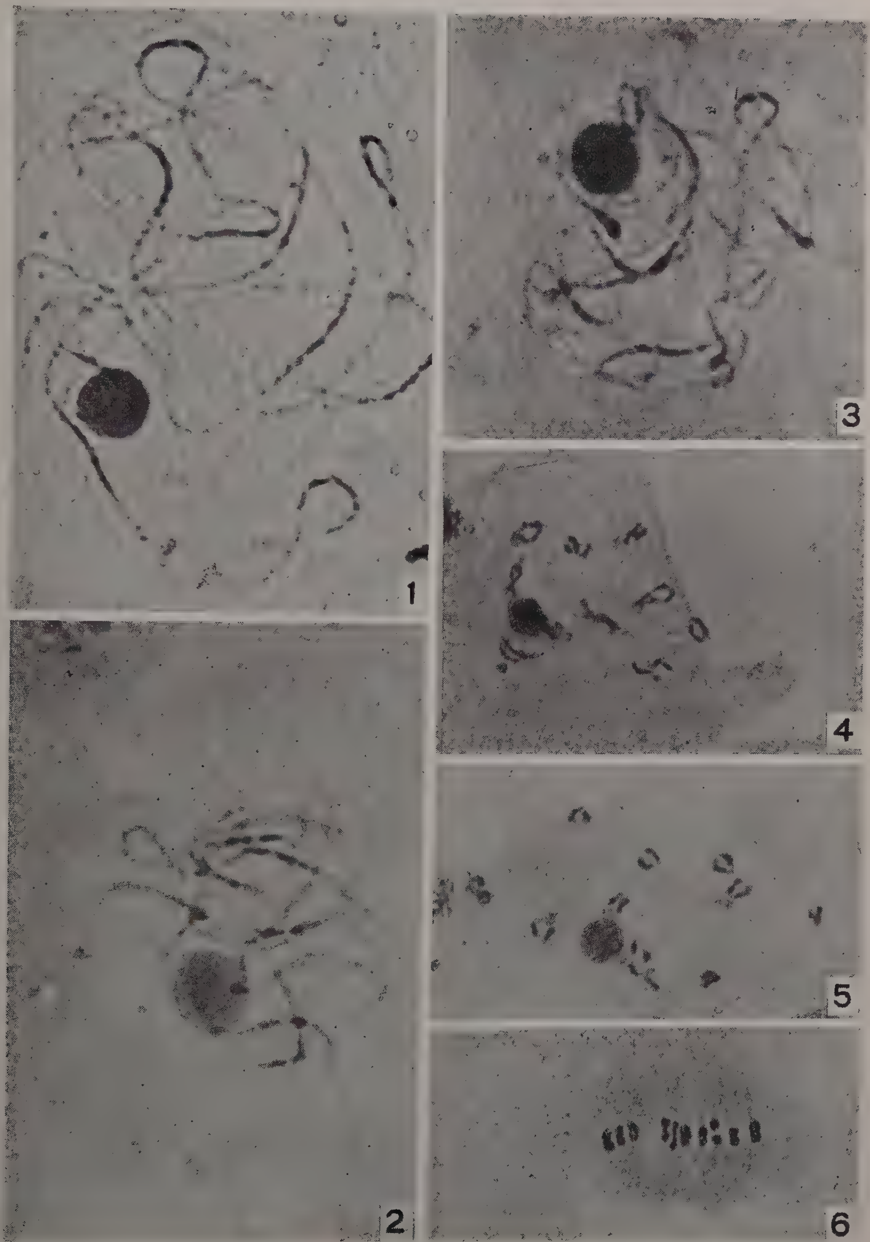


1



2

TEXT-FIGS. 1–2. Fig. 1. Explanatory diagram drawn from Plate XIX, Fig. 1, showing the individual chromosomes (for details of description see text). Fig. 2. Diagram of the pachytene complement in *Sorghum subglabrescens*, showing the average lengths of the chromosomes and the relative lengths of the heavily and lightly stained regions in each. The nucleolar organising region in chromosome 1 is represented by a circle, and centromeres by gaps.



J. Venkateswarlu & V. Ramakrishna Reddi

CONTRIBUTION TO THE ECOLOGY OF TEAK (*TECTONA GRANDIS* LINN. f.) IN MADHYA PRADESH

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Introduction

Teak is the most important timber tree of Madhya Pradesh and the Forest Department has, therefore, been much interested in its ecology and silviculture and several reports and papers have been published. The position prior to 1920 was written up by Troup (1921) and subsequent works have been summed up by Hewetson (1941 and 1951). He directed attention to the lack of data on the relationship of teak to the habitat, particularly the soil. Some observations made by Puri (1951) suggested that teak is probably a calcicolous species showing its best development on base rich soils and on this basis attempts were made to explain its distribution in this country.

With a view to understand the various ecological aspects of this species a study was undertaken during 1952–54 at a number of places in Madhya Pradesh. These include Allapalli (S. Chanda Division), Bori Reserves and Kheli Range (Hoshangabad Division), Punassa and West Kalibhet Ranges (Nimar Division), Hirdaygarh (Chindhwara Division) and various ranges of Sagar Division.

The detailed results of these studies have been recently published (Bhatia, 1955) and the present note embodies details of this contribution on the subject.

(1) *Discontinuous distribution.*—Teak is indigenous to vast areas of South and South-East Asia and has been successfully introduced in areas far removed from its natural limits of distribution (Trinidad, South Africa and Northern India). Throughout the range of its distribution teak forests are rarely pure except where purposive felling of other tree species has been executed; moreover, its distribution is not continuous.

In the State of Madhya Pradesh teak is distributed in a discontinuous manner chiefly in the Satpura Range. At altitudes above 3,000 feet in the Satpuras the discontinuity is due to geomorphological barriers. The changes in the climatic conditions brought about by an increase in altitude does not seem to be suitable for teak. They,

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on the other hand, favour the development of tropical sub-montane forests with semi-evergreen tree species.

In most cases that have been studied the discontinuity is due to edaphic factors in which surface geology and soil play an important part. This had been earlier indicated by Kulkarni (1951). The most spectacular case is to be found at Hirdaygarh. In this region long narrow trap-dykes run through the basal Gondwana sandstones. Teak is confined to narrow bands along the trap intrusions and the phenomenon is repeated at Bori on a more massive scale. Again at Kheli Range, the Satpuras rise abruptly from the plains of Narsinghpur. On the northern slopes of the ranges teak flourishes on the Bagra conglomerates of the Gondwana system forming about 30% of the crop. Further interior on the Jabalpur sandstone teak is predominantly absent. In the same area igneous intrusions bear teak on them. Similar interesting relationships between teak distribution and geological formations have been given by Stamp (1925) in Burma and Kadambi (1951) for Mysore.

The conclusion is that teak requires those minerals which are present in the igneous rock and which have been lost in the Gondwana sandstones. The author's investigation (Bhatia, 1955) show that these minerals include the bases chiefly calcium which is abundantly found in soils derived from igneous rocks. The matrix of Bagra conglomerates contains sufficient amount of calcium and so a good growth of teak is present on them. This brings to the forefront the role of surface geology and soil in the growth and distribution of teak. The present investigation has therefore shown that most soils derived from rocks that contain appreciable amounts of bases support teak (Table I).

Earlier Kulkarni (1951) had stated that "the occurrence of teak is largely confined to soils with pH values ranging from 6·5–7·5" and that intolerance develop "suddenly within a very brief fall of pH value from 6·5–6·0". In the author's investigations (Bhatia, 1955 *b*) he showed that teak occurs in a large number of soil samples between 6·0–6·5. The narrow range of pH tolerance, as indicated by Kulkarni (1951), appears rather insignificant when we consider that his pH determinations were carried out with soil indicator outfit. It has been found that the average exchangeable calcium of 38 samples of soils with pH 6·1–6·5 is 0·39%. This is much above the critical level and most of the good teak stands are supported on these. Thus the statement of De Silva (1934) that the calcicolous plants may occur on soils which are acidic in reaction is largely true for teak. Very few situations have been encountered with pH values between 8·5–9·0 but teak was found to grow well even on such soils.

Besides the bases, soil phosphorus appears to check teak regeneration and distribution over areas where the mineral is likely to be deficient. The suitability of trap soils for teak forests is not only due to the greater water retaining capacity of these soils as pointed out by Champion (1938) but is also due to the higher amounts of soil phosphorus they

TABLE I

The average pH values and the amounts of exchangeable calcium and magnesium in the soils derived from different geological formations of Madhya Pradesh and the teak growth on them

Geological formations	Teak growth	pH	CaO %	$Mg_2P_2O_7$ %
1 Granites and gneisses ..	Medium to good	6·2	0·41	0·28
2 Vindhyan sandstones, shales and conglomerates	Medium to poor	6·0	0·37	0·25
3 Quartzites ..	Poor	6·0	0·26	0·25
4 Gondwana sandstones :				
(*a*) Talchirs, Moturs and Barakars	Poor to nil	5·8	0·24	0·14
(*b*) Bagra conglomerates	Medium	6·6	0·37	0·33
(*c*) Jabalpur sandstones	No teak	6·0	0·23	0·20
(*d*) Pachmari sandstones	No teak	5·6	0·24	0·13
5 Igneous rocks :				
(*a*) Deccan trap	Good	7·1	0·73	0·32
(*b*) Dykes and sills	Good to best	6·3	0·50	0·38
6 Calcareous crystalline	Medium to good	7·6	0·76	0·54
7 Alluvial soils :				
(*a*) Calcareous (with lime)	Good to best	8·3	2·38	0·33
(*b*) Non-calcareous	Best	6·3	0·56	0·46

contain, which is mostly derived from the mineral apatite which forms as much as 1% of trap rocks.

However, the relation of teak distribution to surface geology is not a simple one. At Allapalli (S. Chanda Division) the soils are derived from granite, gneisses and in a few cases from quartzites. These soils are not very rich in bases yet they support good quality teak. This observation opens up another field of study and work on the uptake of minerals under varying environmental conditions is likely to yield results of some value on the physiologico-ecological aspects of the species.

(2) *Concept of teak soils.*—While the present study has helped to bring about the lower limits of various elements of the soil below which teak would not grow the feasibility of building up a concept of teak soils as Hewetson (1941) had pointed out is futile. This is largely due to the fact that many tree species are suited to the average climatic and edaphic conditions of Madhya Pradesh. Which one of these will dominate over a particular area? The answer must be sought not in the soils. Hewetson (private communication) has emphasised this point and explained a few cases where certain species form almost

pure crop while in similar soils derived from the same geological formation in other localities they are prominently absent. Although the role of soil humus, exchangeable bases and moisture can never be under-estimated the underlying explanation of all such cases is a favourable combination of environmental factors which would include in the main the climate. These may occur once in a great number of years but whenever they do combine we have in time and space an almost pure forest of that particular species.

"We can take a tree like Bija (*Pterocarpus marsupium*) with a hard testa. This has to be rotted away before the seeds can germinate freely. This can happen in a year in which there are showers throughout May. Such a year we may imagine, to coincide with a good Bija seed year. What are the chances? Suppose a year with rains in May comes twice a century and a good Bija seed year once every 5 years: the chances of the two coinciding are small. If we further suppose that for the Bija seedling to survive the following rains must be good and last up to October. Such combination of favourable factors may happen once in 100,000 years, but if they do and other things are favourable, then you may get a pure Bija forest in one place."

(3) *Calcicolous habit of teak.*—Following Olsen's (1942) concept of a calcareous plant, teak is definitely a calciphyte, showing best growth and completing all phases of its life on soils with high concentration of exchangeable calcium.

The high foliar calcium content (3–6%) in teak further confirms its calcicolous habit.† This shows that calcium plays an important part in the growth and distribution of teak in the State.

(4) *Divergent physiological behaviour.*—Many of the difficulties are in part due to the lack of correct information on the uniformity of teak population. This prevents generalisation over larger areas. Studies on foliar calcium is a definite pointer in this direction. As has been stated earlier (Bhatia, 1955) the divergent results of the various investigators may be due either to the different physiological races present in nature or that the nutritive balance of the plant is disturbed when introduced in areas outside its natural limit. Definite information on either of these points is very important. It is natural to expect complexities in a mixed population, while on the other hand, information on the nutrition of teak when planted away from its 'home' is of immense practical value to the forester.

(5) *Significance of calcicolous habit.*—Chandler (1939) has classified trees with foliar calcium up to 3% as 'soil improvers' because of the relatively large amounts of calcium they deposit on the soil surface each year. This is largely true of acidic soils with low lime content in the northern temperate zone. In our conditions there are, however, indications to show that such a view may not be tenable in teak areas.

† The values obtained for teak leaf is high when compared with calcium content of other forest trees worked out by Puri and Gupta (1950). Chandler (1939) considers values above 3% as high.

Teak makes a heavy demand on soil calcium and removes a good amount from the soil. If for some reason or the other the amount of calcium stored in the leaf is not returned to the soil the nutrient capital of the soil may greatly diminish and a good percentage of this element shall have to be written off. Such adverse circumstances are in fact many. It is well known that due to sparse undergrowth in teak forest the top soil is subject to easy erosion (Laurie and Griffith, 1941). The repeated summer fire reduces the litters to ash which is either blown off or washed away with the first downpour of rain. Much of the bases concentrated at the top may thus be lost.

Again, Brandis (1921), in one of his notes on teak, had recorded that the white mineral deposits in wood cavities of teak is "as far as known mainly consists of calcium phosphate". Although no data on the total calcium locked up in the wood is available at the moment, nevertheless, the observation is of particular interest. The amount of calcium present in the wood is perhaps lost to the soil after the trees are felled and removed.

Puri (unpublished) has observed that the plantation of teak in sal (*Shorea robusta*) area has led to the depletion of soil calcium as teak makes a higher demand on soil calcium, ... "ultimately when the sub-soil has become acidic, teak will probably suffer and may naturally give place to sal seedlings." This observation is in line with the present contention that soils under teak may in course of time, under circumstances mentioned, lose its bases.

Taking this view, it is possible to explain the results of Laurie (1931). He found no significant difference between teak and non-teak soils of Anamalai Hills, Madras. He obtained uniformly acid conditions under both (average pH value for teak area is 5·56 and for non-teak soil is 5·68) and the soils were deficient in lime. It is possible that these conditions have developed later on as a result of the depletion of bases, for these soils do not seem to represent ideal conditions for the growth and distribution of teak and that the present crop may be the last after which teak would be replaced by other less exacting species, as in the adjoining areas.

Again, it is possible to explain, on basis of high calcium demand, the reason why the species does not occur gregariously.

There have in fact been many opinions about the deterioration of soils under teak (Casten, 1933 and Laurie and Griffith, 1941), but till now no direct explanation has been put forward. It now appears likely that it may be due to the depletion from the soil of calcium salts that are locked up in the wood or largely removed from the top layer by sheet erosion.‡

‡ Subsequent work carried out at Dehra Dun on mineral economy in teak plantation has shown that there are no chances of calcium depletion. However, the investigation has brought out the possible depletion of the important soil mineral phosphate since it is stored in fairly large quantities in the wood and indications are there to show that the depletion of this mineral may lead to failure in regeneration, discontinuous distribution and deterioration of forest site leading to fall in quality class.

(6) *Practical importance of the present results.*—Griffith and Gupta (1947) by their study of some teak soils of Nilambur plantation found that "calcium and magnesium are usually high in alluvial soils where good quality teak exists and this may be ameliorative to soil conditions even though it may not be essentially needed for teak" (Table II). They developed a method to forecast the quality of teak on the ratio of SiO_2/RZO_3, dispersion coefficient, depth of permanent moisture availability and aspect.

Using their 'four factor' index many of the Gondwana soils in Madhya Pradesh may be classified as good teak soils. But these soils rarely support teak (Table I) for the simple reason that they do not contain sufficient amount of exchangeable bases. Thus, it appears from the evidence derived from the distribution of teak on calcareous soils and from foliar analysis, that calcium is involved in the metabolism of teak.

The importance of soil bases was emphasised by Diebold (1935) who stated that the soil characteristics of the greatest importance for tree growth would include, besides others, the lime content of the entire soil profile.

It will yet take much investigation to bring out the precise role of calcium in the metabolism of the species, nevertheless, the results of the investigations of Griffith and Gupta (1947) for the Nilambur Plantations (Table II) and those of the present studies, clearly shows that calcium could be correlated with better growth of teak and greater frequency distribution. It is, therefore, clear that unless calcium is included as an important soil characteristic for the forecast of teak quality, it is doubtful if the results of Griffith and Gupta (1947) would have a wider field of application.

Other factor that favours the development of the species is soil phosphorus which from the view-point of plant nutrition is much more important than the bases and the consideration of this fact will necessitate better understanding of the factor where widespread afforestation of teak forests is likely to be undertaken.

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TABLE II

The relation of soil calcium to planted teak quality in Nilambur (compiled from Griffith and Gupta, 1947)

Name of plantation	Soil type	Aspect and topography	Teak quality classes	Total CaO % classes 0·1–0·3	0·31–0·60	0·61–0·90	0·91–1·20	1·21–1·50	1·51–1·80	1·81–2·10	2·10–2·50	Above	Total No. of soil samples studied
Kanhiraka dara ..	Alluvium	..	Good	..	3	1	3	4	1	..	..	..	12
do	do	N. Aspect	Good	..	..	4	4	1	..	2	..	1	12
Walluvasseri Comptt., 151–53	do	Foot-hill	Good	..	2	2	1	4	..	..	..	..	10
Pennengode Comptts., 134–35 and 137	do	..	Best	..	..	5	..	..	..	..	..	..	5
do Comptt. 120,	do	..	Good	..	1	1	..	1	..	..	..	..	3
Nellicutter Comptts., 431–34	do	..	Best	..	..	1	..	2	..	1	..	..	4
Pennengode Comptts., 134–35 and 137	Thin alluvium overlying Laterite	..	Poor	..	2	3	..	..	..	..	..	..	5
do	do	..	Failed	4	1	..	..	..	..	..	..	..	5
Kanhiraka deva ..	No alluvium	Hill-top	Poor	2	12	5	2	1	..	..	..	..	24
Walluvasseri Comptts.1951-53	do	Hill-top	Little teak	1	3	..	..	..	..	..	..	..	4
do	do	..	Little teak	4	1	..	..	..	..	..	..	..	5
Nellicutter Comptts., 431–34	do	Foot-hill and S.W. slopes	Poor	..	6	3	..	..	..	..	..	..	9
do	do	Hill-top S.E. and E. slope	Deteriorated teak	6	4	..	..	..	..	..	..	..	10
Walluvasseri Comptts., 151–53	Laterite	..	Failed	10	2	..	..	..	..	..	..	..	12
Pennengode Comptts., 120	Swamp	Hill-top	No teak	6	3	..	..	..	..	..	..	..	9

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On two species of *Solenopora* from the Cullygoody Limestone of the Trichinopoly District, S. India.
S. R. N. Rao, M.A., *Botany Department, University of Lucknow.*

Plant fragments from Devonian beds in Central Yunnan, China.
J. Hsü, *Botany Department, University of Lucknow.*

A silicated cocos-like palm stem, *Palmoxylon* (*Cocos*) *Sundaram* from the Deccan Intertrappean beds.
B. Sahni, D.Sc., Sc.D., F.R.S., *Botany Department, University of Lucknow.*

Algal succession on a rocky island, named Charaiguha, in the Chilka Lake.
P. Parija, M.A. (Cantab.), D.Sc., and **B. Parija,** *Utkal University, Cuttack.*

On the structure and life-history of *Aulosira bombayensis* sp. nov.
Ella A. Gonzalves, M.Sc., *Royal Institute of Science, Bombay.*

Nipanioruha granthia gen. et sp. nov.; a new petrified coniferous shoot from the Rajmahal Hills, Bihar.
A. R. Rao, D.Sc., *Botany Department, University of Lucknow.*